AEAS / ESAPP / SLM Eritrea Joint Report

An Appraisal of the Current Status and the Potential of Surface Water in Upper Anseba Catchment, Eritrea

Abraham Daniel
Filmon Tesfaslasie
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2009

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Publisher:
Geographica Bernensia
Bern, 2009

This study and the publication of this report were funded by Eastern and Southern Africa Partnership Programme (ESAPP). Additional financial and logistic support came from CDE (Centre for Development and Environment), Bern, Switzerland within the framework of Sustainable Land Management Programme, Eritrea (SLM Eritrea).

Citation:
Abraham Daniel, Filmon Tesfaslasie, Selamawit Tesfay, 2009
An Appraisal of the Current Status and the Potential of Surface Water in Upper Anseba Catchment, Eritrea
Bern, Geographica Bernensia, 151 pp.
Ministry of Agriculture, SLM Eritrea, and ESAPP, Syngenta Foundation for Sustainable Agriculture, and Centre for Development and Environment (CDE), University of Bern, 2009

Publisher:
Geographica Bernensia

Printed by:
Varicolor, Switzerland

This publication was prepared with support from:
This study and the publication of this report were funded by Eastern and Southern Africa Partnership Programme (ESAPP). Additional financial and logistic support came from CDE (Centre for Development and Environment), Bern, Switzerland within the framework of Sustainable Land Management Programme, Eritrea (SLM Eritrea)

English language editing:
Theodore Wachs, Marlène Thibault, Thomas Kohler (pp. 1–6, 111–118)

Layout:
Simone Kummer, Centre for Development and Environment (CDE), University of Bern

Cover photos:
By the authors

Copies of this report can be obtained from:
The Association of Eritreans in Agricultural Sciences (AEAS),
P.O. Box 4826, Asmara Eritrea
E-mail: aeas321@Yahoo.com
Tel ++291 1 18 10 77
Fax ++291 1 18 14 15

Eastern and Southern Africa Partnership Programme (ESAPP)
Centre for Development and Environment (CDE)
University of Bern
Hallerstrasse 10
CH-3012 Bern, Switzerland
Tel ++41 31 631 88 22
Fax ++41 31 631 85 44
E-mail info@cde.unibe.ch
www.cde.unibe.ch

ISBN
978-3-905835-14-4

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Abbreviations and Acronyms

AW	Available Water
CDE	Centre for Development and Environment
CWR	Crop Water Requirement
DEM	Digital Elevation Model
DFID	Department for International Development
ECS	Eritrean Catholic Secretariat
ERRA	Eritrean Relief and Rehabilitation Agency
ESAPP	Eastern and Southern Africa Partnership Programme
ET	Evapotranspiration
ETc	Crop Evapotranspiration
ETo	Potential Evapotranspiration
FC	Field Capacity
GIS	Geographic Information Systems
GMA	Groppo Mission Asmara
GoE	Government of Eritrea
GPS	Global Positioning System
Kc	Crop Coefficient
KR2	Kennedy Round 2 (funded by Japan Development Cooperation)
MAD	Management Allowable Depletion
MAP	Mean annual precipitation (mm)
MoA	Ministry of Agriculture
MoLWE	Ministry of land, Water, and Environment
MoND	Ministry of National Development
NFIS	National Food Information System of Eritrea
NGO	Non Governmental Organization
PRA	Participatory Rural Appraisal
RS	Remote sensing
SASE	Signs of active erosion
SLM	Sustainable Land Management Programme
SPOT	Systeme Probatoire d'Observation de la Terre
SSY	Specific Sediment Yield
UoA	University of Asmara
UTM	Universal Transverse Mercator
VC	Vegetation condition
WRD	Water Resource Department
Lt	Litre
t/ha/yr	Tonnes per hectare per year
km^2 or sq.km.	Square kilometer
m.a.s.l	Meters above sea level
Sy	Sediment yield (t/km^2/year)

Foreword

Surface water has been the main water source for crop production, livestock watering and domestic supplies in Zoba Maekel in the Upper Anseba Catchment.
The main sources of surface water in this Zoba are dams and ponds; most of the dams built after Independence were intended for both irrigation and domestic supply purposes, whereas those built under the colonial regimes were mainly intended for domestic water supply purposes.

Today, rainfed agriculture is becoming unreliable in most places due to climate change. It is thus time to shift at great speed from rainfed to irrigated or supplementary irrigated agriculture. As we know, without access to water there is no food. Population growth is leading to increasing demand for agricultural products in terms of both quality and quantity. Productivity must be increased in order to meet this demand, and this can only happen if water harvesting is maximized by tapping ground water resources and introducing micro-irrigation systems where possible. It is known that some of our dams are silted and the volume of water they retain has dropped far below the original capacity. In view of this fact it is very important that we learn from our past experiences and treat the catchments of dams in order to prevent siltation and improve degraded land before constructing a dam. Moreover, it is equally important to desilt the dams where the water level is reduced in order to increase the capacity of our dams.

Last but not least I thank and appreciate Eng. Abraham Daniel and the team of experts for their contribution in preparing this comprehensive document which can be used as a source of baseline data and a guideline for Upper Anseba Catchment and Zoba Maekel.

Heruy Asghedom
Director General
Agricultural Promotion & Development Department
Ministry of Agriculture

Acknowledgements

We would like to express our gratitude to the Ministry of Agriculture (MoA) Maekel Region and to the Eastern and Southern Africa Partnership Programme (ESAPP) for the joint agreement that created the ground for this study. We would like to thank ESAPP for the funds it provided for carrying out the research, and the Centre for Development and Environment (CDE) of the University of Bern and SLM Eritrea (Vision Eritrea) for their moral, logistic and financial support. The study could not have been initiated without the contribution of SLM Eritrea and the effort and encouragement of Paul Roden.

In addition, the authors warmly thank Dr Thomas Kohler from CDE and Dr Albrecht Ehrensperger from ESAPP for their support during the study, for their continuous encouragement, and above all for their comments on the final draft. Special thanks go to Dr Woldeslassie Ogbazghi (ESAPP country focal point) and Engineer Amanuel Negassi (Irrigation, Division Head, MoA) for their tremendous job in reviewing and editing the document.

We wish to express our gratitude to MoA Maekel staff members for their support during the field work and workshops. We are especially indebted to the field enumerators for their assistance and cooperation during the tedious field data collection, in particular to Kesete Ghebregiorgis and Mussie Wolday, who in addition to data collection contributed a great deal in collecting secondary data from MoA archives.

Above all, we would like to thank all the farmers who were very cooperative during the field work and throughout the study, providing us with valuable information about their environment and their farming experiences.

Abraham Daniel
Filmon Tesfaslasie
Selamawit Tesfay

Executive summary

Background

Water resources are increasingly under pressure in many parts of the world. As scarcity of water becomes more marked, so increases the need for sustainable and improved water management in order to meet the growing demand for drinking water for larger populations, as well as for sanitation, agriculture and industry. This is also the case in Sub-saharan Africa.

Water stored in reservoirs is a means to alleviate seasonal water shortage during dry periods. It offers a way of guaranteeing year-round irrigation and ensuring that there are little or no domestic and drinking water shortages for the local population in periods without rain. As a Sahelian mountain country, Eritrea has over the last decades made considerable efforts to increase the number of reservoirs in order to mitigate the effects of seasonal water shortages resulting from scant and unreliable rainfall. But the current knowledge relating to development and management of surface water – and specifically reservoirs – has remained sketchy. Sustainable land management and water resources development are threatened by soil erosion and high sedimentation rates. In addition, knowledge of water resources in terms of quantity and quality is insufficient. This study hopes to narrow this knowledge gap by appraising the current status and potential of surface water storage and use, based on the need to enhance sustainable use of reservoirs for irrigation, livestock watering and domestic purposes in a developing economy.

Upper Anseba Catchment

The study deals with the Upper Anseba Catchment, which is located in the central highlands of Eritrea. This area was chosen because it is one of the most densely populated areas in Eritrea, with a large number of stakeholders and a great diversity of water uses, including urban and industrial uses as well as agriculture, which is dominated by small-scale farming. Like most other regions of the country, the Upper Anseba Catchment has no perennial surface water course. Upper Anseba covers a total surface area of 633 km^2. It is very largely included in Zoba Maekel, one of the country's six zones, of which it forms the Northern half (Maps 1.1 and 1.2). Rainfall is generally inadequate and unreliable, especially for rainfed farming. The dominant soil type in the catchment is vertic luvisol, which covers 66% of the area. Geologically, the Upper Anseba Catchment is dominated by low-grade metamorphic rock consisting of chloride and basic metavolcanics. The moist highland agro-ecological zone covers 99% of the area, while the remaining 1% falls under the sub-humid agro-ecological zone. A land use and land cover map of the catchment reveals that rainfed farming is the most widespread category of uses, covering about 70% of the area. 13% are open and sparse shrubs, 7 % urban areas, 5 % tree plantations, 4.5 % irrigated agriculture, and the remaining 1% is covered by bare soil and artificial water bodies.

Methods

The study is based on literature and document review, which was followed by an extensive field survey in two phases; in phase one, a general survey of all reservoirs in Zoba Maekel – including the Upper Anseba Catchment – was carried out, while in phase two, detailed quantitative and qualitative data was collected on 9 selected case study reservoirs and on 4 local communities, both with and without access to a reservoir. Remote sensing (RS) and Geographic Information System (GIS) techniques were used along with participatory appraisals.

Number of Reservoirs and Design Capacity

The study found that there are 74 reservoirs within Zoba Maekel, with an aggregate water holding capacity of 67 million m^3. Most of these reservoirs were built within the last 20 years. The catchment sizes of these reservoirs, delineated via a Digital Elevation Model (DEM), ranges from 0.15 to 141 km^2. The relationship between catchment size and reservoir capacity is weak. Of these 74 reservoirs, 49 are located within the Upper Anseba Catchment; of these 49, 11 are used to supply water for Asmara, the largest town in the area. The remaining reservoirs are used for irrigation, livestock watering, and rural water supply, including domestic use. Average design capacity of all 74 reservoirs is 850,000 m^3, and aggregate design capacity 67 million m^3. Aggregate design capacity of the 49 reservoirs in the Upper Anseba Catchment is 32 million m^3.

Siltation and Current Storage Capacity

While design capacity was taken from secondary data, siltation rates and hence current reservoir capacity rates were estimated based on bathymetric surveys in 9 selected reservoirs, and through catchment modeling according to DFID. The results show that 11 to 45% of the original (design) capacity of the reservoirs has been filled up with sediments over the past two decades. The average is 23%. Sediment yields vary between catchments; the range extends from 262 $t/km^2/year$ to 1769 $t/km^2/year$, with an average of 856 $t/km^2/year$. The sediment deposition measurement from the bathymetric survey gave specific sediment yields ranging from 132 $m^3/km^2/year$ to 1846 $m^3/km^2/yr$, with a mean value of 703 $m^3/km^2/yr$. The corresponding annual sedimentation rate is 0.5–2.0%.

Rainfall and Runoff as Input Values

In Upper Anseba, rainfall is the only input that can be tapped for water storage. Rainfall was calculated by using the records of five gauging stations within the study area. The data was used to produce an isohyetal map. This made it possible to determine the average yearly input across the Upper Anseba Catchment, which is about 289 million m^3 of water. This generated about 41 million m^3 of runoff, based on a runoff coefficient of 14% as an annual average. As the surface reservoirs have a potential capacity of 32 million m^3, almost 70% of this annual runoff can be stored at present (2007).

Current Water Use and Irrigation

Out of the total of 74 reservoirs in Zoba Maekel, 31 are used for irrigation (class one reservoirs), of which 19 are located in the Upper Anseba Catchment. Three of the 31 reservoirs (Adisheka, AdiNifas_D01 and AdiNifas_D02) are mainly used for town water supply, and irrigation is limited to seepage water downstream of these reservoirs. A total area of 446.5 ha was found to be currently irrigated from class one reservoirs within Zoba Maekel. Irrigation is also practiced from 15 class two reservoirs in the Zoba, 10 of which are located in the Upper Anseba Catchment. The area irrigated with water from these reservoirs is 40.5 ha and thus much smaller than for the class one reservoirs.

Overall, therefore, a total area of 487 ha is currently irrigated from the 46 class one and class two reservoirs in Zoba Maekel. Of this, 346 ha are located in the Upper Anseba Catchment.

Potential Water Use and Irrigation

Based on design capacity and deducting the volume lost to siltation, the potential irrigation area of the 46 reservoirs where irrigation is currently practiced was found to be 833 ha for Zoba Maekel, of which 475 ha are within the Upper Anseba Catchment. This means that by using the existing dams more effectively, an additional 346 ha could be irrigated within the Zoba (129 ha thereof in the Upper Anseba Catchment).

Constraints for the Expansion of Irrigation

The main constraint for the expansion of irrigation is availability of water. In addition to irrigation, almost all villages use reservoir water for watering livestock and often for drinking, cooking and washing, as well. These uses take precedence over irrigation, even if the water comes from reservoirs. Land scarcity and especially inefficient water use are further constraints. Water conveyance in the area is mainly by open channel, or by open channel combined with lined (concrete) channel or piped systems. Water is lifted or delivered to the channels using diesel- or petrol-operated water pumps. In places where the irrigated plots are close to the reservoir, farmers use buckets to fetch water and irrigate their fields directly. Most farmers irrigate once a week, unless the crops are at flowering stage and in need of more water; however the schedule used by farmers during this period varies and is not known. The soil-water budget method could assist users in deciding when to irrigate and how much water to apply.

As to socio-economic constraints, Participatory Rural Appraisals (PRAs) and group discussions in 4 communities helped to gain insight into the perceptions and ambitions of the communities relating to reservoirs and their use. The main findings include the fact that rural communities in Zoba Maekel are still predominantly subsistence-oriented, adopt risk-minimising strategies and thus rely on different sources of income to secure their livelihood. Prioritization of activities and their contribution to household income was also studied, and it was found that the higher the income from an activity, the higher the commitment of the villagers to that activity. While the wish for expanding irrigation is high on local agendas, specialization in one specific activity such as irrigation was found only in one case (Lamza); typically, this community has several decades of experience in irrigation. But in general, water is still managed the traditional way despite the new by-law that came into force in 2004. In the majority of the villages there is no water association, and little expertise - if any -relating to modern and more effective ways of irrigation management.

Recommendations

Based on the information collected, the authors of this study recommend the introduction and promotion of water-efficient irrigation systems. There is also an urgent need for less water-demanding and higher-yielding crops. Moreover, it is advisable to explore other sources of water, such as fog harvesting and roof catchments, to supplement supplies delivered from reservoirs. Furthermore, establishing and strengthening water user associations is as important as technical development; the same is true for the preparation and enforcement of a comprehensive by-law to regulate water use. Generally, access to markets is good, but may have to be improved where rural access roads are in bad condition. Overall, it is also crucial to prepare a coordinated water use and development master plan at catchment level that includes all sectors with a demand for water, including urban and rural residential, industrial, recreational and ecological uses. For a more detailed summary of recommendations, readers are referred to Chapter 5 of this report.

1 Background

Water is one of the most crucial natural resources for human existence. Especially in developing countries like Eritrea, where the majority of the population directly relies on the productivity of the land, it is a fundamental prerequisite for development and food security.

Eritrea as an arid and semi-arid Sahelian country is not endowed with abundant water resources and is threatened by recurrent drought. The average precipitation in the country is about 384 mm/yr (FAO, 2004) with only 1% of the total area receiving more than 650 mm of annual rainfall (FAO, 2005). What makes the situation worse is that rainfall in Eritrea is torrential, has a high intensity, short duration, and varies greatly from year to year (FAO, 2005). Except for the Setit River which is perennial, all rivers are seasonal and flow for a short period of time during and after periods of rainfall and run dry for the rest of the year. There are no natural freshwater lakes in the country. Groundwater can be tapped in all parts but not in the quantity and quality desired (FAO, 2005; NEMPE, 1995). The overall picture for Eritrea is that water is in essence a very limited resource.

The importance of small reservoirs for the local population in most arid and semi-arid environments cannot be overestimated. Water stored in these reservoirs allows irrigated agriculture and ensures a constant supply of domestic and drinking water for all during dry periods. Among the various uses, water for the purpose of growing agricultural products has become a major issue in Eritrea today, as rainfall is inadequate and uncertain over large parts of the country, and population is growing.

Since the Italian colonial period many reservoirs have been constructed in Eritrea and especially in the densely populated central highlands, including the Upper Anseba Catchment with its total surface area of 633 km^2. Since the 1930s, 49 reservoirs have been constructed in the Catchment. The area has a wide range of economic sectors and includes different stakeholder and hence interest groups: In the rural areas rainfed and irrigation agriculture are the main economic activities, whereas in the urban areas and particularly in Asmara, the country's capital, society depends on the availability of water for a wide range of uses including domestic and industrial. Overall, water is becoming increasingly scarce.

Cleaver and Schreiber (1994) indicate that as the trend towards increasing industrialization continues water resources scarcity increases, too. In Upper Anseba, there is thus a need to increase the effectiveness of water resources management in order to meeting the demands for drinking water of a growing population, for sanitation, agriculture and industry. This present research work is mainly motivated by signs of increasingly competitive utilization of reservoir water for irrigation, livestock watering and domestic use (rural and urban water supply); its aim is to create a basis for the enhancement of these uses on a sustainable basis, with a focus on irrigation.

If the use of reservoirs for irrigation and domestic purposes is to become more efficient and productive, there should be precise and up to date information on the existing situation relating to reservoirs and to the size of the irrigated and potentially irrigable land downstream. A careful study providing quantitative information and understanding relating to the current situation, including a proper analysis of current problems are essential. Such a study could form a basis for informed decision making and policy formulation.

1.1 Maekel Zone

In administrative terms, 85% of the Upper Anseba Catchment is within Maekel zone (Zoba Maekel), and lies in its Northern part (Maps 1.1 and 1.2). General statistical information on Upper Anseba is thus based on data extracted from the Zoba. Maekel zone is one of the six administrative regions (zobas) of Eritrea. It is the smallest region in the country with a total area of 1,040 km^2. It borders Zoba Debub in the South, Zoba Anseba and Zoba Semenawi Keih Bahri in the North, Zoba Semenawi Keih Bahri in the East, and Zoba Gash Barka in the West (Map 1.1). Maekel zone lies between 15°10' – 15°35'N latitude and 38°41'– 39°30'E longitude, and at an altitude of between 1276 to 2625 m with an average of 2200 m.a.s.l.

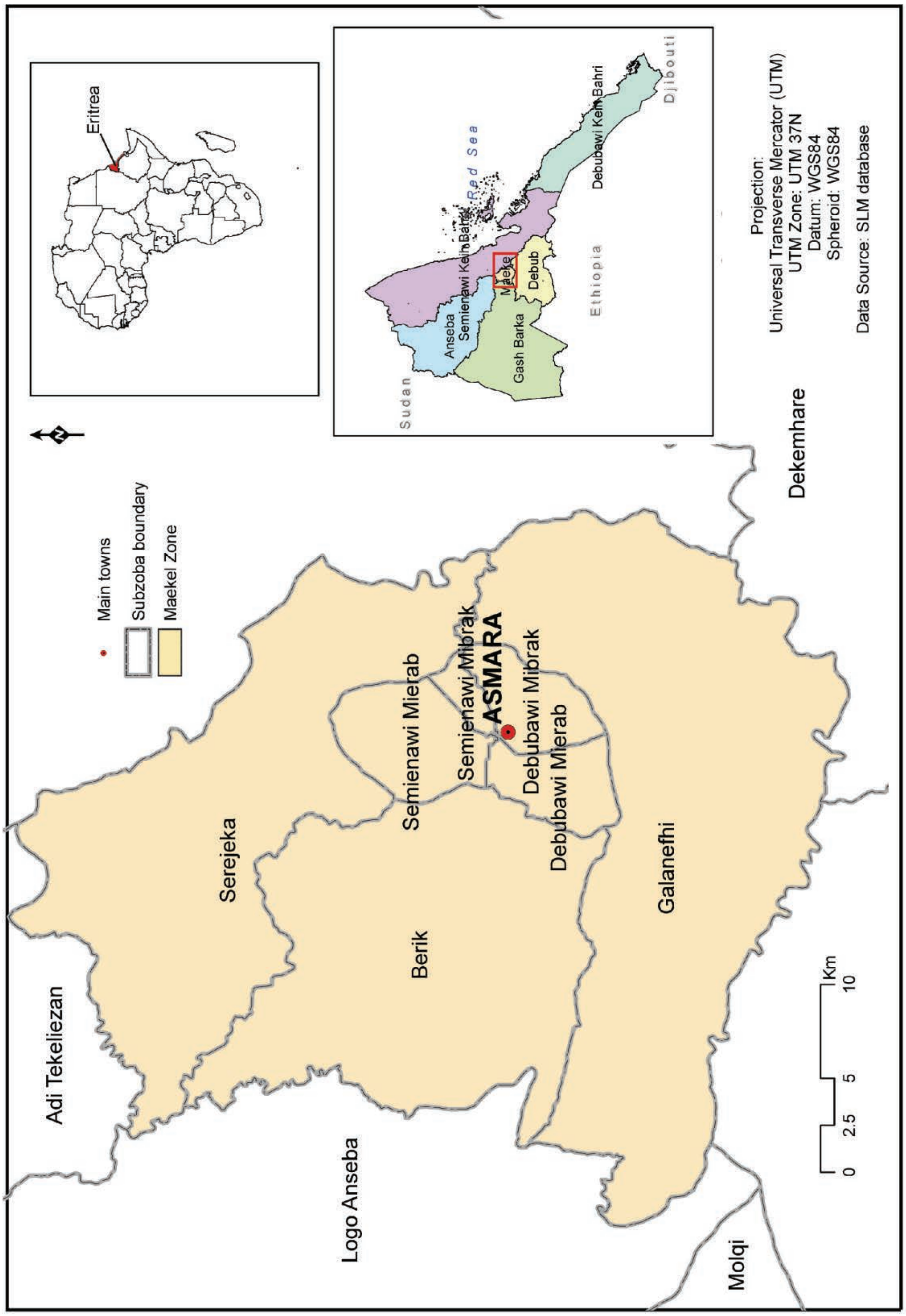
The zone has 7 subzobas and 85 villages with an estimated population of 518,400 in about 114,600 households (Administration Office of Maekel Zone 2008). The four smaller subzobas comprise the area of the city of Asmara; the three larger ones include the rural areas (Map 1.1). According to the Ministry of Agriculture branch office of Maekel Zone, 27%of the total population is engaged in agriculture, 23.5 % in trade and services, 18% in manufacturing and handicrafts, while 7.5 % in civil service and 24% in casual labor.

According to the Ministry of Agriculture branch office, about 47,000 ha (or 45%) of the total land of the zone are rain-fed, 24,000 ha (23%) are grazing land, 7,300 ha (7%) are forest area, 1,000 ha (1%) are irrigated and the remaining 24,600 ha (24%) are used for residential housing and other buildings, and also include the land not suitable for agriculture.

The region can be divided into two major agro-ecological zones namely moist highland (92%) and sub humid (8%). This division is done on the basis of moisture and temperature regimes, natural vegetation cover, soils, and land use (Kifle and Randcliffe, 1997). These two agro-ecological zones are further divided into 7 agro-ecological units based on more specific differentiation of landform, soil type, land cover or land use. The moist highland has five agro-ecological units, while the sub-humid part (comprising the eastern escarpment) has two.

The climatological data available for Maekel shows that the Zoba's rainfall is generally inadequate and unreliable. The main rainy season is between June and August with short rains between March and May. Annual rainfall records from MoA Maekel from 1997 to 2007 show a maximum of 574 mm in 2001 and a minimum of 297 mm in 2002. The mean annual rainfall during these 11 years was 418 mm (Appendix 1).

The mean maximum and mean minimum annual temperatures of the region are 25.5 °C and 4.3 °C. All subzobas experience the same climatic condition except subzoba Serejeka to the North which experiences warmer temperatures. Sunshine is between 10 -14 hours per day.



Map 1.1 Administrative Map of Maekel Zone (Zoba Maekel)

1.2 Upper Anseba Catchment

River catchments provide a natural unit for water management. Thus a watershed boundary was used to delineate the study area. A catchment approach is also important as water management involves all stakeholders upstream and downstream as well as the physical environment that influences, for example, surface runoff.

The study area comprises the upper part of the Anseba River basin, one of the five main basins in Eritrea, with a total area of 12,198 km^2. The river originates in the vicinity of Asmara and flows northwest through a rough terrain towards Keren. It then continues in a northeasterly direction, changes its course towards the North, joins the Barka River and finally drains into the Red Sea. The river reaches the sea only in years of higher rainfall. Even though the Anseba River basin drains a small watershed, on average the unit runoff is relatively high (Woldetzion, 1991).

The Upper Anseba catchment has a total area of 633 km^2, 85% of which lies within the administrative boundaries of Zoba Maekel, 8 % in Subzoba of Logo Anseba, Zoba GashBarka and 7% with in Subzoba of AdiTekelezan, Zoba Anseba (Map 1.2).

1.2.1 Topography

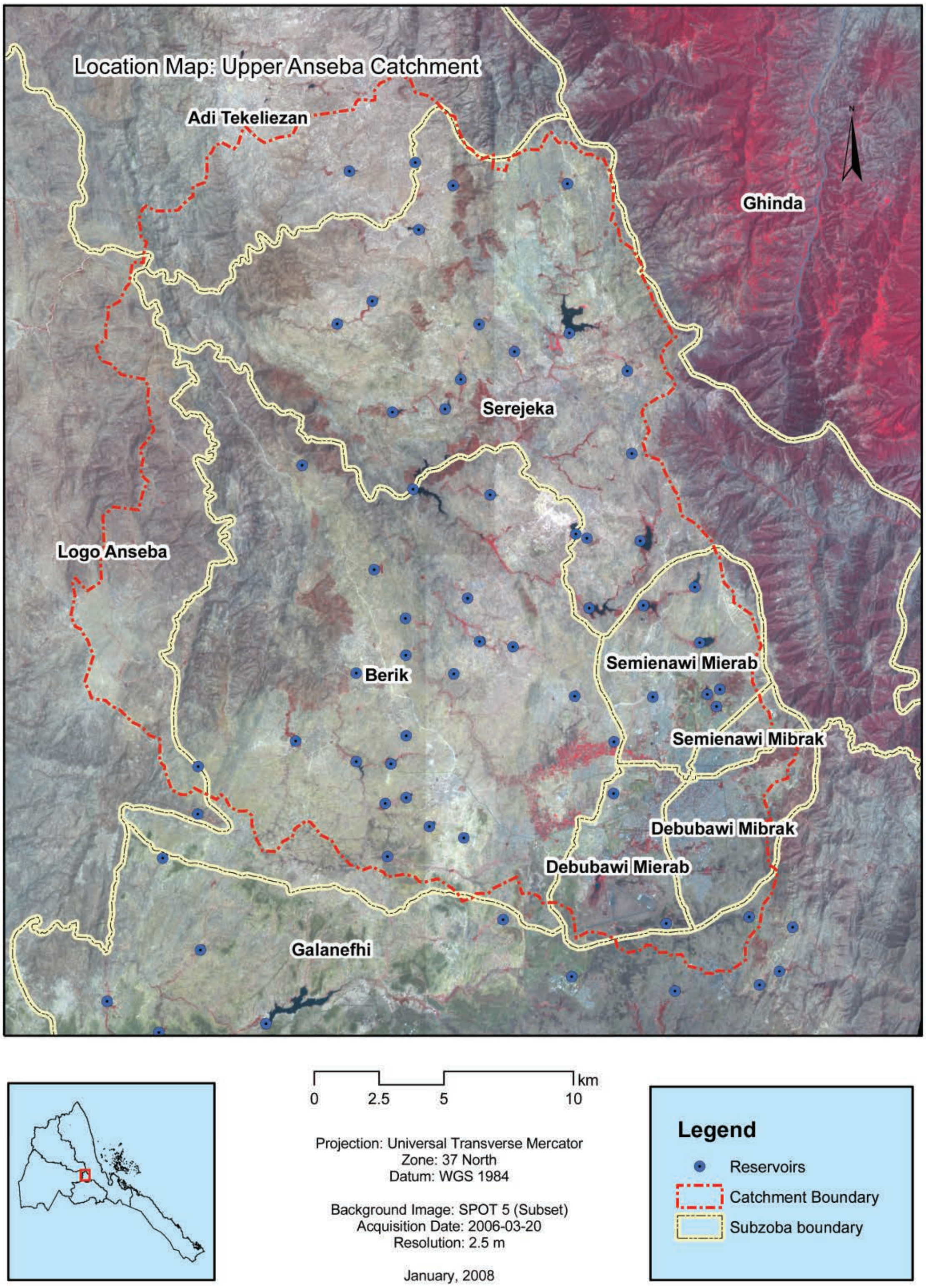
A large part of the catchment is dominated by gentle to almost flat landforms with some hills and undulating areas (Map 1.3). The plain and undulating areas cover 78%, while 21% are made up of slightly or moderately steep slopes with a slope of 8-30 degrees. In this area, there are also few mountains and river gorges covering 1% (Table 1.1).

Table 1.1 Slopes (in degrees) of the Upper Anseba Catchment

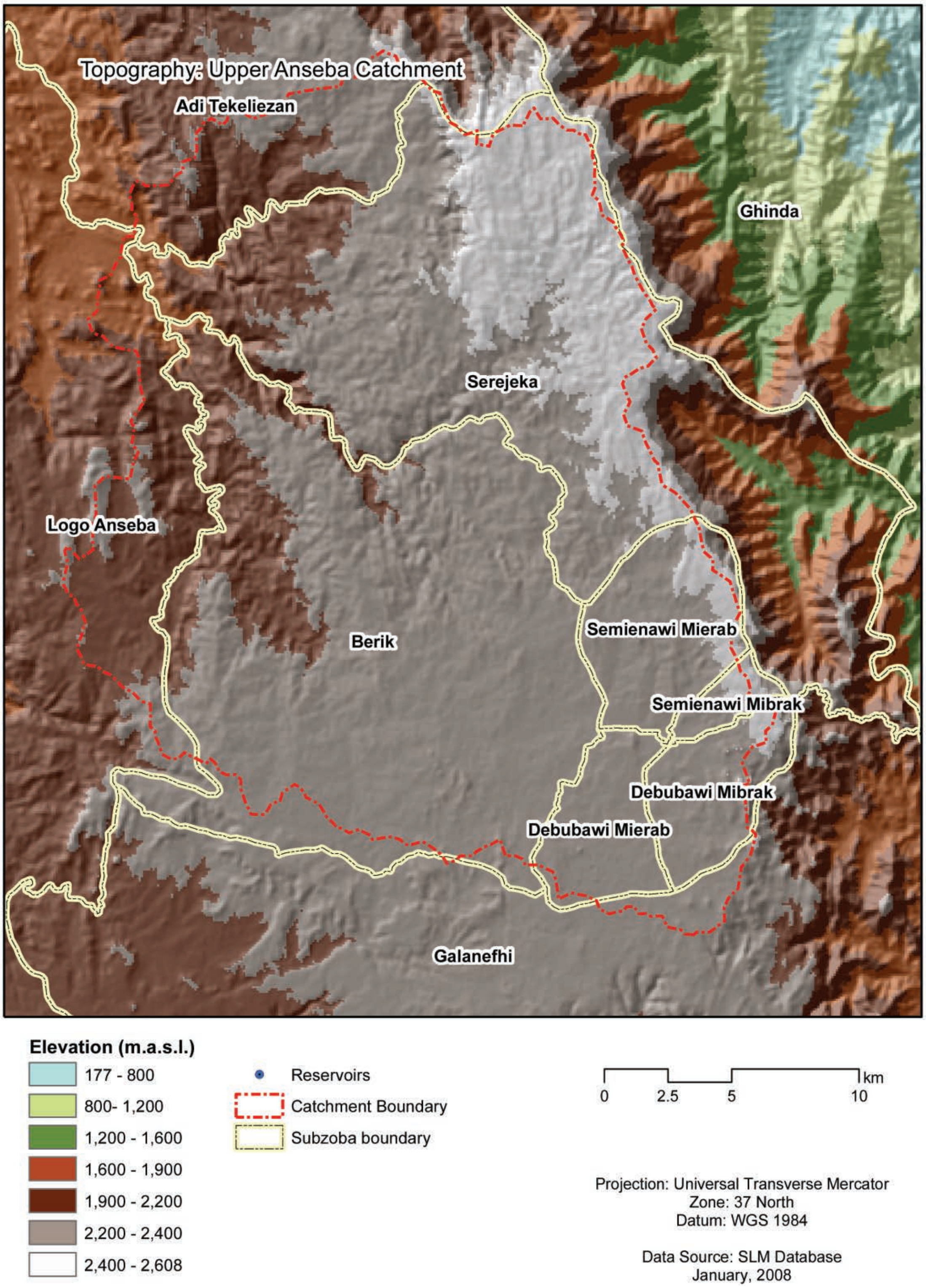
Slope in degrees	Landform	Area in Hectares	Percent from total
0-2	Plain	14,817	23 %
2-8	Undulating	34,727	55 %
8-15	Slightly steep	9,742	15 %
15-30	Moderately steep	3,801	6 %
>30	Steep	188	1 %
Total		63,275	100%

1.2.2 Vegetation

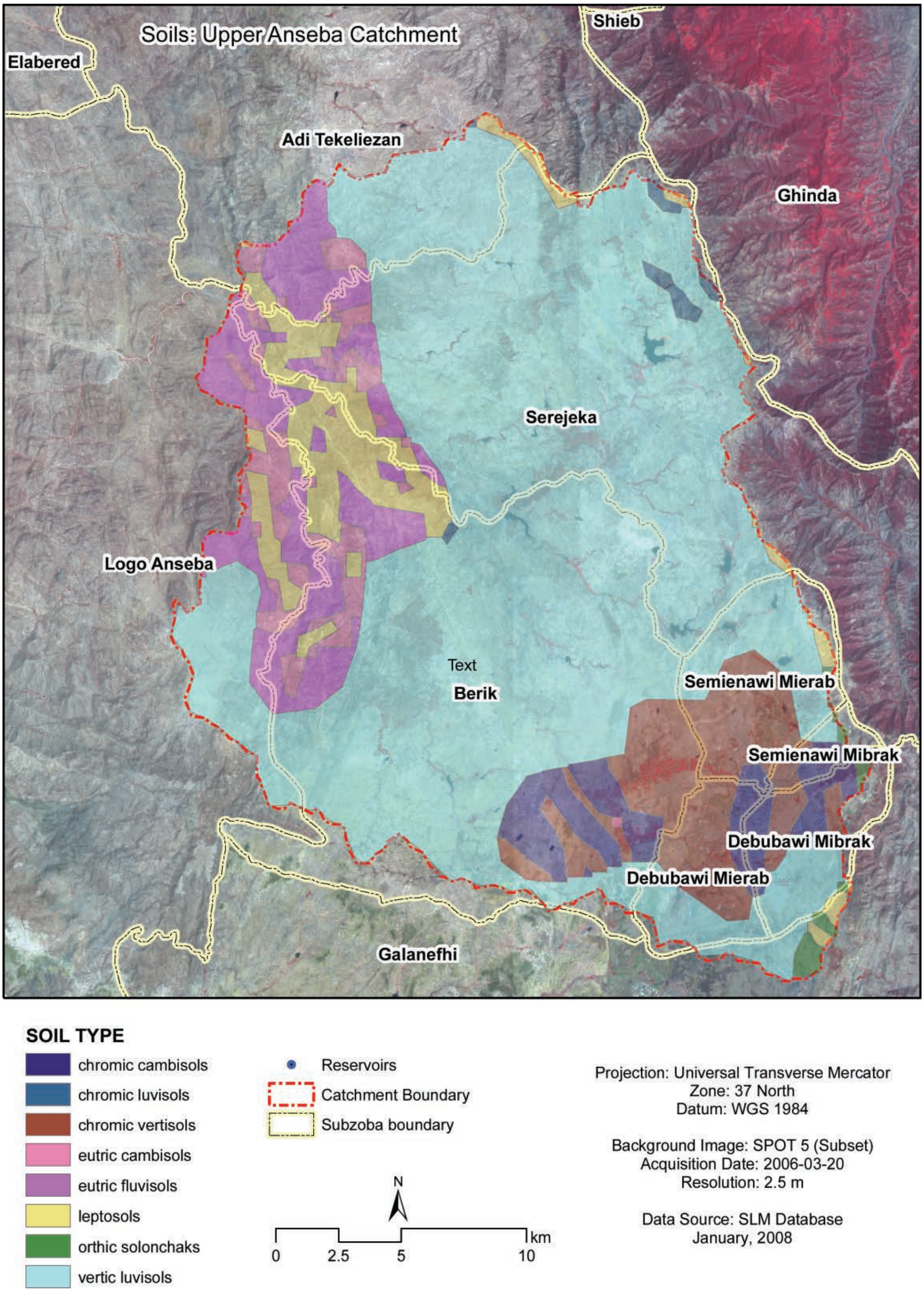
Except for the community plantations of eucalyptus trees and some pockets of natural forests with small bushes and shrubs, the catchment is not endowed with natural vegetation. Most of its area is deforested and degraded by water and wind erosion. In the small pockets of vegetated areas that exist, mainly in Subzobas Berik and Galanefhi, the dominant trees and shrubs include Acacia-tortilis (a'lla), Acacia etbaica (seraw), Dodnaea-angustifolia (tahses), Euclea-schimperi (kilaw), Becium-grandiflorm (tahbeb), and Rumex usambarensis (hehot). Most of the community plantations, found especially in subzoba Serejeka, are dominated by Eucalyptus and Acacia species.



Map 1.2 Upper Anseba Catchment



Map 1.3 Topography of the Upper Anseba Catchment



Map 1.4 Soils of the Upper Anseba Catchment

1.2.3 Soils

According to the general soil map of Eritrea (FAO, 1988), the dominant soil type in the catchment is vertic luvisol, covering 66% of the area. The second most important soil types are eutric fluvisols and chromic vertisols covering 9% of the area each. Leptosols and cambisols are also found but to a smaller extent (Map 1.4), generally on steep slopes and rolling hills and are mostly used for grazing because of their poor potential for crop production.

In general land degradation is widespread in the study area. A long history of cultivation and grazing as well as fuel wood and timber harvesting without recycling of nutrients or management of organic matter has resulted in poor soils and depleted vegetation.

1.2.4 Geology

Geologically the Upper Anseba catchment is mostly composed of low-grade metamorphic rocks of chloride and basic metavolcanics. This rock is of Precambrian age exposed to several tectonic incidences of various degrees. Due to these, the geology is relatively complex and characterized by faults and fractures. Their dominant orientation is N-S and NW-SE. Tectonic movements have also caused different degrees of alteration, which have endowed this area with gold and other base metal deposits. Relatively speaking, these metavolcanics are a soft rock type and highly weathered and fractured to some tens of meters of depth.

The Southern part of the catchment is covered by younger granites and granodiorites formed during the major tectonic era and therefore relatively less fractured (Map 1.5). On the Northern side of the catchment, post tectonic granites are dominant. They have coarse-grained minerals indicating the plutonic nature of the rock. These granites were less exposed to pressure and high temperature and are therefore massive and less weathered.

The youngest formation in the catchment is the trap basalt series, which forms the underground under the Southern part of Asmara. It extends further to the South and reaches into the Northern part of Ethiopia. These basalt lava series are characterized by massive formations at the lower end of each series, and by softer formations towards the top of each series due to the vesicular openings.

1.2.5 Climate

Based on records over 11 years (1997-2007), mean annual rainfall is 450 mm, with a maximum of 628 mm registered in 1997 and a minimum of 295 mm in 2002. As can be seen from Figure 1.1 and Table 1.2, rainfall in the area is low. It is also torrential and unevenly distributed and as a result rainfed agriculture is a very risky basis of livelihood. Thus, it would be essential for farmers to increasingly engage in irrigation in order to supplement the low production and income obtained from rain-fed agriculture.

The main rainy season is between June and September and is known as ‘Kremti’. There is a short rainy season in March and April locally known as ‘Asmera’. Apparently, the duration of the long rains (June-September) has been decreasing over the years.

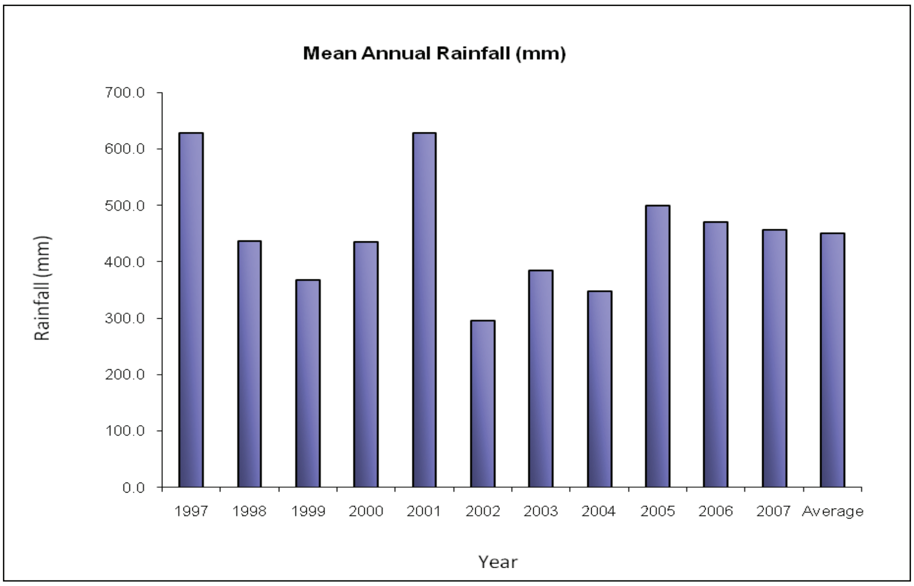


Figure 1.1 Mean annual rainfall (mm) in Upper Anseba (1997-2007)

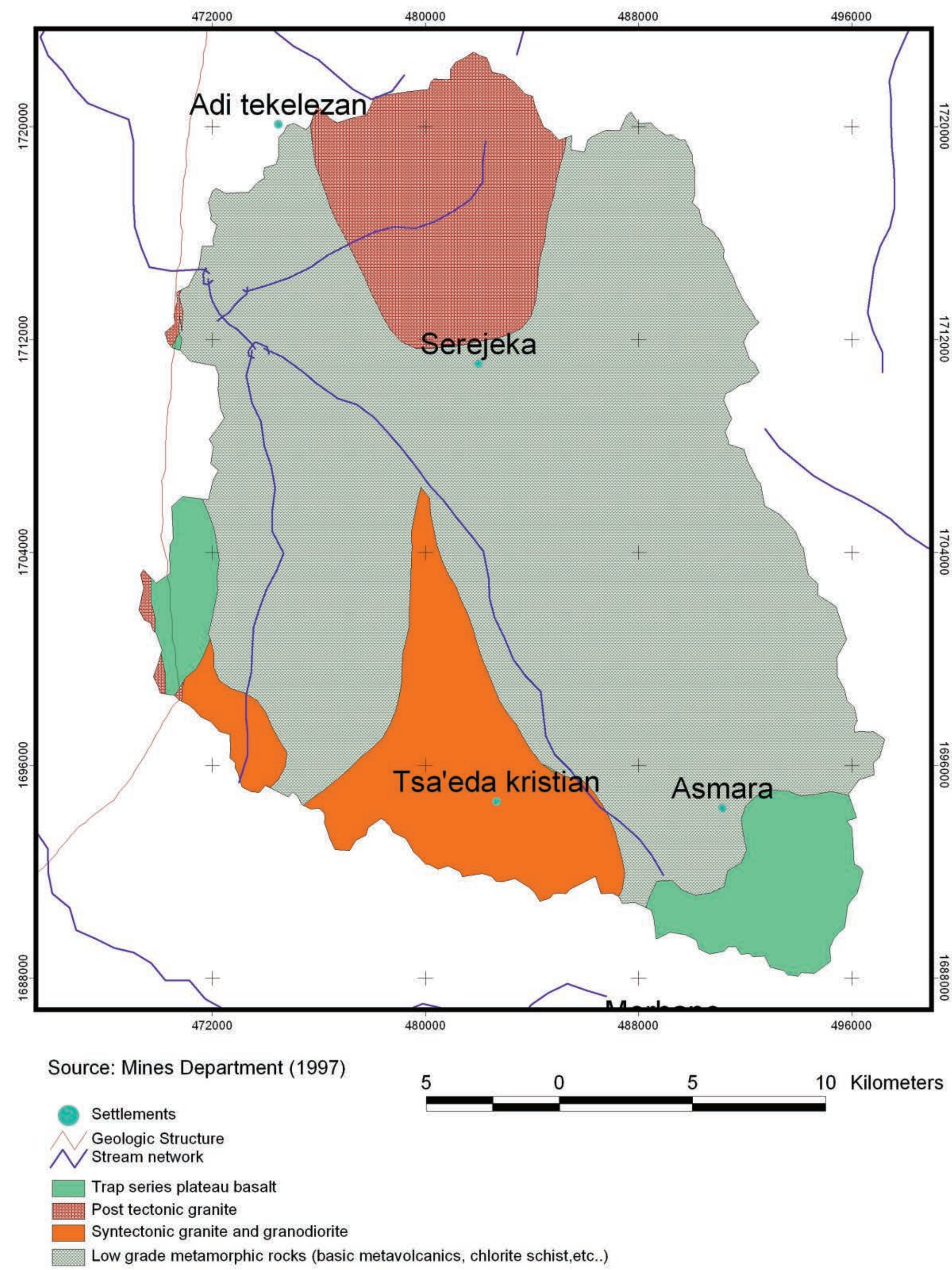
Table 1.2 Mean annual rainfall (mm) for selected stations (1997-2007), Upper Anseba

Stations	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average
Bet Giorgis				365.5	603.9	372.4	394.7	288.1	485	642.1	575.2	465.9
AdiNefas							393.7	294.4	590.1			426.1
Tsaedachristian	717.3	439.8	332.4	499.6	530.6	383.8	366.9	301.1	498.6	391.9	409.2	442.8
Tseazega	556.5	343.3	243.1	351.2	506.0	221.8	278.6	292.4	378.1	368.5	401.3	358.3
Hazega	591.0	344.0	295.5	531.7	819.3	380.3	422.1	296.1	541.2	398.5	473.6	463.0
Afdeyu	648.0	618.8	601.9	407.1	625.9	179.5	405.6	430.8	324.0			471.3
Hayelo				388.0	564.4			351.4				434.6
Geremi				568.2	607.9	220.7	415.5	421.1	630.0			477.2
Embaderho				372.6	814.0	327.8	383.2	391.8	463.9	405.9	533.1	461.5
Serejeka				436.0	576.0	273.1	397.1	413.7	587.5	617.4	349.0	456.2
Mean Annual Rainfall (mm)	628.2	436.5	368.2	435.5	627.6	294.9	384.2	348.1	499.8	470.7	456.9	450.1

Source: MoA-Zoba Maekel

The mean annual temperature in the study area is 18.4 °C. The average monthly maximum and minimum temperatures are 26.5 °C and 14.1 °C respectively. The warmest months are March through May with a mean monthly maximum of 23.8 °C and the coldest months are from November through February with a mean monthly minimum of 9.2 °C.

The agro-ecological zones are the same as for Zoba Maekel. The moist highland agro ecological zone covers 99% of the Upper Anseba catchment while the remaining 1% falls under the sub humid agro ecological zone.



Map 1.5 Geology of Upper Anseba Catchment

1.2.6 Land Use, Land Cover, and Land Tenure

A land cover map of the catchment (Map 1.7) compiled from Africover data and a land cover map that covers part of the area (Burtscher 2003) reveals that about 70% of the area are under rainfed agriculture (large to small scale, scattered and isolated), 4.5% are under irrigated agriculture, 5 % are tree plantations, 13% open and sparse shrubs, 7 % urban area, while the remaining 1% are covered by bare soil and artificial water bodies.

In Eritrea in general, the government owns the land and farmers have the right of use. The land tenure system which is dominant in the central highlands is the ‘Diessa system’. Under this system, farm land is redistributed among eligible farmers every 5-7 years. While preventing landlessness, this mechanism has led to fragmentation of land and has discouraged farmers to make long-term investments on their land.

Figure 1.2 Adi Asfeda, rainfed agriculture: The dominant land use type in Upper Anseba

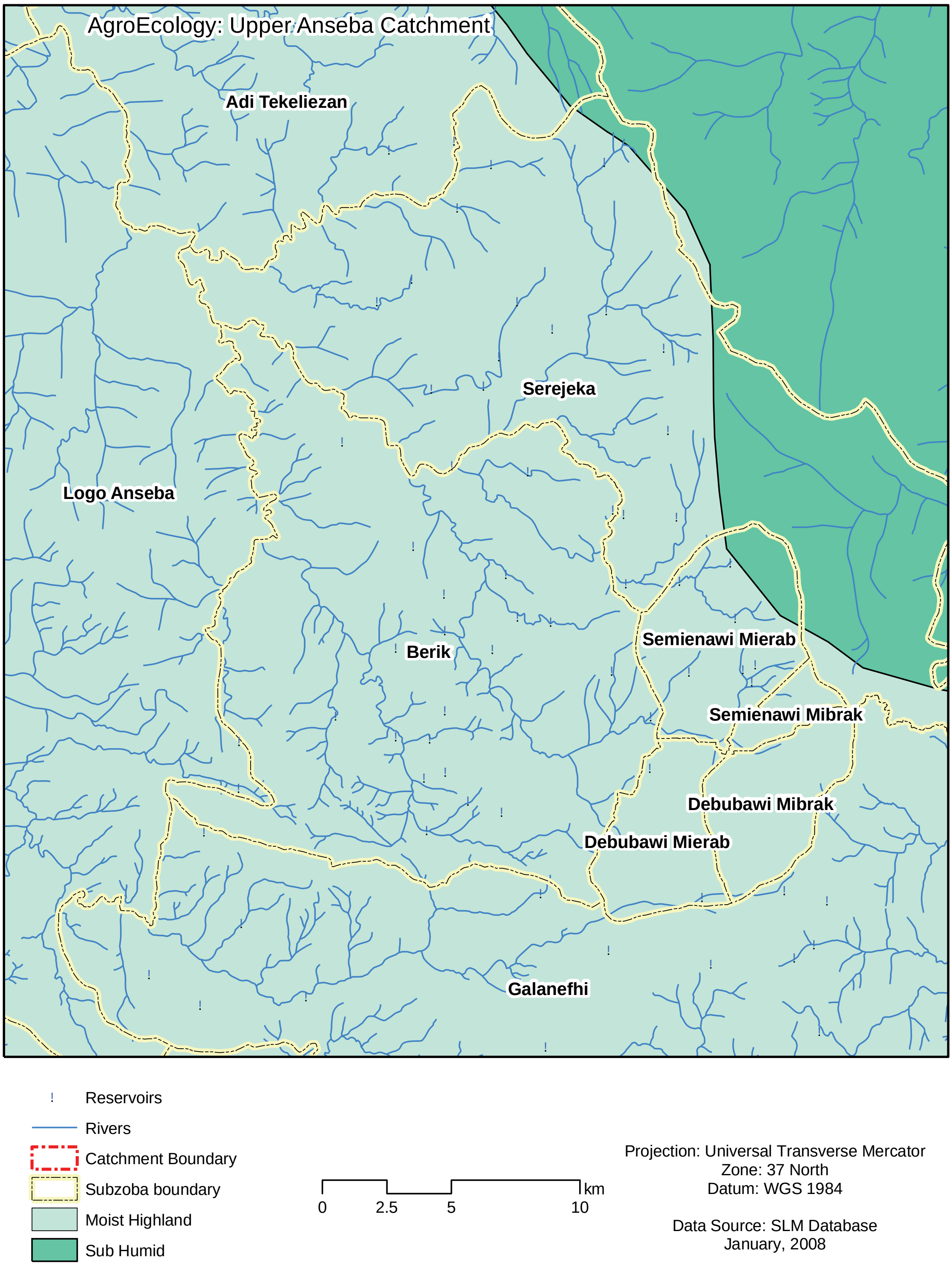
1.2.7 Water Resources

There are no major rivers in the study area which could be used for large-scale irrigation. Dams, wells and Maibela River, a small water course, are the main sources of water and are mostly used for small-scale irrigation and for domestic water supply. It is important to note that the quality of water from Maibela is very poor as a result of sewage and industrial effluents. The effluent is used for irrigation to produce vegetables and forage crops, though. This is posing a significant health hazard to human and livestock population in the area, especially to the population of Asmara where most of the produce is sold.

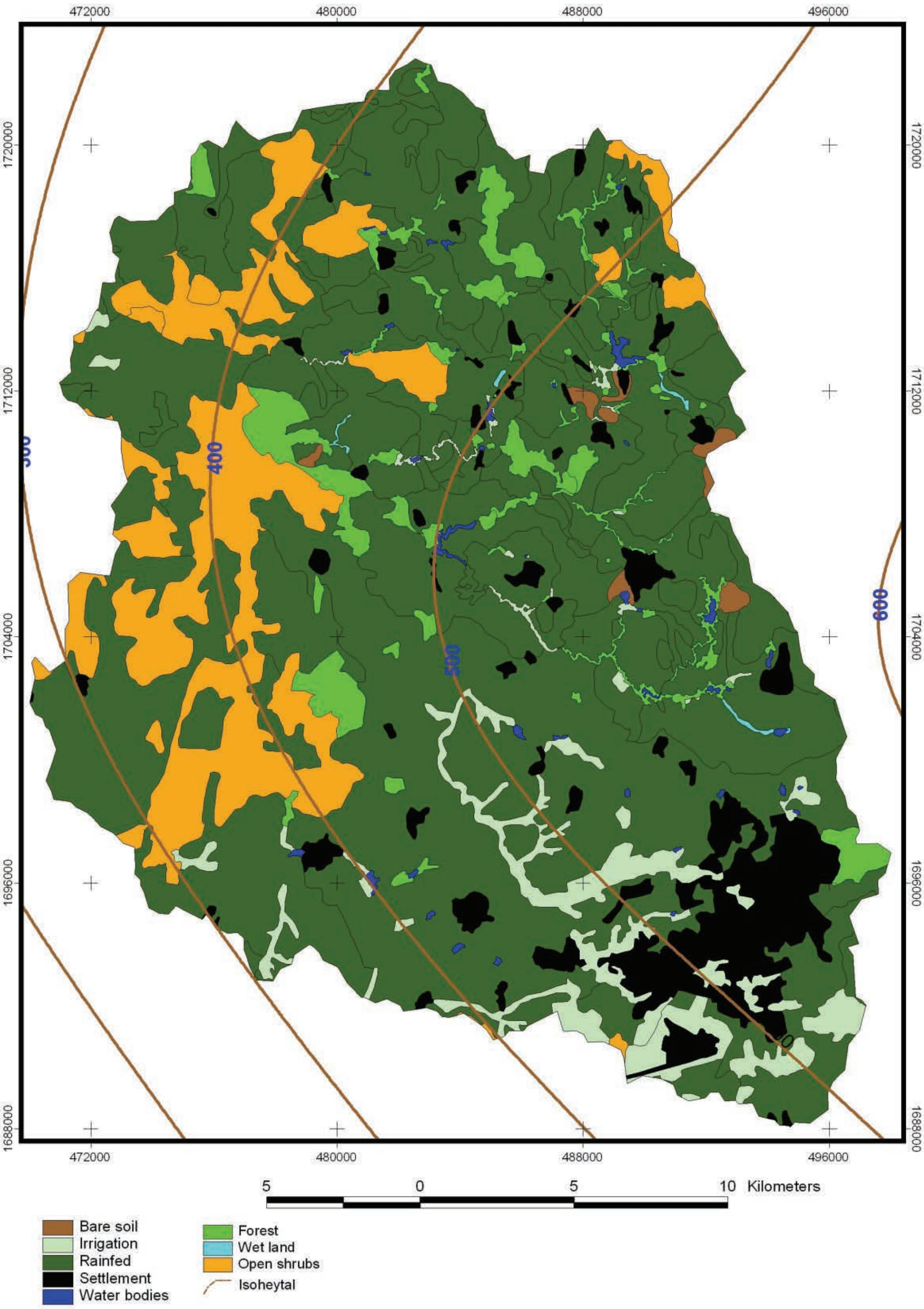
1.2.8 Farmers’ Associations and Extension Services

Agricultural extension services are provided to farmers at subzoba branch offices. There are currently five associations in Zoba Maekel with a total membership of 1,126 engaged in horticultural production, cattle fattening, beekeeping, and poultry and dairy production.

These associations have their own management committees comprising a chairperson, secretary and treasurer. Toker Project is providing these associations with technical and financial support. The project has so far assisted the associations in the establishment of 10 village shops in the Zoba with the aim of providing members with easy access to agricultural inputs such as fertilizers, chemicals, veterinary drugs, chicken, selected seeds, and farming tools. These village shops have their own management committees which include representatives of farmers, village administration and the project (NFIS, 2005).



Map 1.6 Agro ecology of the Upper Anseba Catchment



Map 1.7 Land cover of Upper Anseba Catchment

1.3 Problem Statement

Since the Italian colonial regime, many community reservoirs have been constructed in Eritrea. These reservoirs represent an important component of agricultural development, be it as a source of drinking water, for livestock, for recharging of groundwater downstream, or for irrigation.

In Eritrea, reservoirs provide an effective coping mechanism for dry years. They are secure sources of water and are more reliable than ground water especially in the central highland, where the geological formations do not hold large bodies of water. The government is thus continuously trying to identify more efficient use of reservoir water so as to get higher and more sustained yields and to improve food security at both household and national levels.

Mugabe et al. (2004) explained that generally the sustainable use of water is constrained by insufficient knowledge of the resource in terms of quantity and quality and by the lack of proper water resource management. Unfortunately, the current knowledge on development and management of surface water and specifically on reservoirs is sketchy in Eritrea. The exact number of existing reservoirs as well as the quantity and quality of their water are not known. Little recorded information is available regarding size and condition of the areas that drain into the reservoirs.

Moreover, sustainable land management and water resources development are threatened by soil erosion and sedimentation. Though sediment deposition in reservoirs is a serious off-site consequence of soil erosion in Upper Anseba, there are no reliable sediment-yield data. Such data would be important for designing new reservoirs and for implementing soil conservation.

Even though the extent of the area irrigated with water from reservoirs has been increasing in recent years, it is still insignificant compared to the number of reservoirs and their aggregate volume, as will be confirmed by this present study. Thus, efforts have to be made to increase and improve the irrigation systems and to increase their overall efficiency.

Considering the above, it is crucial to assess the water resources that are available in order to create a basis for informed decision making in support of planning and implementing systems of water management which enhance the effective use of water and which promote sound management for increasingly competing uses in Upper Anseba.

1.4 Objectives of the Study

The general objective of this study is to create a basis for informed decision-making processes regarding the use of surface water for community members, planners, implementers and policy makers. It addresses the shortcomings in stakeholder participation and the information needs required for more efficient management of surface water in Upper Anseba.

The study includes an assessment of surface water availability and use, current management practices, and touches upon awareness raising and capacity building relating to the major stakeholders, with a view of improving overall performance of irrigation. These are all building blocks for better planning, implementation, and management of surface water, with a focus on reservoirs. Overall, therefore, this study aims to make a contribution to sustainable development within Upper Anseba.

1.4.1 Specific Objectives

Specific objectives of this study are:

- To create a spatial database on water use and management with a focus on dams and reservoirs based on high-resolution satellite image maps, to address the lack of information required by planners, implementers and policy makers as a basis for informed decisions for a more efficient management of surface water. Resources allocation must be fair and be based on the needs of the population; but on the other hand, it must take into account the generating capacity of the Catchment.
- To evaluate the general characteristics and problems of reservoirs in Zoba Maekel with a focus of those within Upper Anseba Catchment.
- To assess the extent and efficiency of water use of the existing irrigation systems, and to estimate possibilites and potentials for extension of the irrigable area.
- To estimate the extent of sediment deposition in selected reservoirs.
- To assess community perceptions and ambitions of water use regarding the existing reservoirs.
- To identify promising practices, methodologies and approaches that could serve as pilot schemes for replication and for a more effective use of water in general in the study area and the highlands in general.

2 Methodology

The methodology used for this study was based on a holistic approach, which comprised quantitative as well as qualitative components, with the aim of capturing information from different angles relating to stakeholders and environments, in order to reflect the diversity of situations found within Upper Anseba.

2.1 Site Selection

According to Ogbagabriel (2001) more than 30% of the Eritrean population lives in the moist highland zone, which makes up only 7.4 % of the total area of the country. The Upper Anseba Catchment is one of the most densely populated areas in Eritrea with a wide range of economic sectors and stakeholders, including residential, industrial, and farming. Of the 49 reservoirs within the Catchment, 11 are used for town water supply of Asmara. The others are used for irrigation, livestock watering, rural water supply including domestic supplies. Thus the Catchment has been selected because there are different and conflicting demands for water and hence there is urgency for sustainable management of water resources.

2.2 Literature Review and Field Survey

Work for this study started with a review of literature and other written material related to reservoirs, their history, previous inventories, livestock and irrigation activities, and other related topics on the area. This was followed by a field survey in two phases. Phase one comprised a general survey of all reservoirs existing in Zoba Maekel, which included those in Upper Anseba. Phase two focused on the collection of detailed quantitative and qualitative information on 9 selected case study reservoirs.

Phase one of the field work also included a survey of all villages of Zoba Maekel which have a reservoir on their territory, which was carried out by 10 trained enumerators using a semi structured questionnaire (Appendix 2). A total of 75 reservoirs were studied. The survey also collected general physical data related to catchment characteristics, reservoir condition, irrigation activities and infrastructure. This data was processed and encoded into a database and spatial GIS dataset.

The enumerators who undertook the work were extension workers of the Ministry of Agriculture of Zoba Maekel. They were chosen because of their experience in administering questionnaires and in interacting with the respondents at all levels. Prior to field work, a two-day orientation took place and the questionnaires were pre-tested. The results are presented in Chapter 3 of this study.

The 9 reservoirs studied in-depth in the second phase were selected according to reservoir size, spatial distribution, current water use and management, and irrigation activities. Age of reservoirs and accessibility were secondary factors in the selection. Survey activities focused on the quantitative assessment of the natural resources within the catchment level of the reservoir; on reservoir capacity, and on downstream irrigation areas. Sampling and laboratory analyses were also carried out to assess the physical soil properties of a number of representative spots within the irrigated area of the reservoirs. For each of the 9 reservoirs, a list of recommendations relating to water management and irrigation development was prepared. The results are presented in Chapter 4 of this study.

2.3 Remote Sensing and GIS Data Analyses

Remote Sensing and GIS techniques were extensively utilized in this study. Recent SPOT 5 georeferenced satellite imagery with 5m spatial resolution captured on the 20th of March 2006 was used to locate all reservoirs, to prepare satellite image maps for field data collection, and to generate a land use-land cover map of the study area. In a separate step, the catchment area of each reservoir was calculated from DEM with 50 m grid size derived from Russian maps prior to fieldwork. Both the satellite image and DEM data processing and mapping were done in GIS using ArcGIS 9.1 GIS software.

During field visits, the maps prepared from the SPOT5 satellite imagery and from secondary feature datasets were verified. The location of all reservoirs was taken using hand held Global Positioning System (GPS) in Universal Transverse Mercator (UTM) projection. In addition, GPS measurements were used to accurately measure the crest length of the reservoirs and to delineate boundary and area of upstream and downstream irrigated fields.

Figure 2.1 Extension worker collecting GPS data to calculate dam crest length, Adi Keshi

2.4 Estimating Actual Reservoir Capacity and Sediment Deposition

For a water resources assessment in the central highlands of Eritrea, information on the capacities of the reservoirs is crucial. A bathymetric survey was done to determine current water volume and present capacity of the reservoirs. The distance from the water surface to the top of the sediment was measured at more than 20 spots on each of the selected reservoirs, using a small boat with a depth counter and a GPS. These data were used to create bathymetric maps and to calculate water volumes as well as current storage capacity.

Sediment deposition was estimated by comparing the results of the field survey, i.e. current storage capacity, with the original design capacities according to information obtained from the Ministry of Agriculture of Zoba Maekel.

Figure 2.2 Bathymetric survey at Embaderho reservoir

Generally speaking, there are three methods for estimating sediment yields:

- Sediment yield from stream flow sampling,
- Reservoir re-survey data, and
- Catchment characterization method including mean annual rainfall data.

In the present study, reservoir re-survey and catchment characterization were used to estimate the amount of siltation for the selected reservoirs. The reservoir re-survey was based on the procedure described above.

Relating to catchment characterization, which is a relatively subjective approach, mean annual precipitation data, secondary raster and feature datasets, and field observation including information from key informants were used to derive scores representing the characteristics of the catchments (Appendix 3). Based on the scores given to vegetation condition, soil type, drainage, and signs of active erosion, the sediment yield was calculated for the selected reservoirs using the equation below (DFID 2004):

$$Sy = 0.0194 * Area^{-0.2} * MAP^{0.7} * Slope^{0.3} * SASE^{1.2} * STD^{0.7} * VC^{0.5}$$

where:
Sy – sediment yield (t/km^2/year)
Area– Catchment area (km^2)
MAP– Mean annual precipitation (mm)
Slope– River slope from the catchment boundary to the dam
SASE– Signs of active erosion (Score from catchment characterization)
STD– Soil type and drainage (Score from catchment characterization)
VC– Vegetation condition (Score from catchment characterization)

2.5 Qualitative Data Collection

The qualitative component of the survey provided contextual information essential for understanding current water use and management. It included focus group discussions with selected farmers, and water committees where they existed; key informant interviews with administrators and representative farmers; and participatory rural appraisal (PRA). PRA was conducted in selected villages to assess community perceptions on how to use a dam, ambitions (potential of the dam as perceived by the community), and to identify and prioritise constraints of agricultural production.

Field work also included discussions with zonal officials and other relevant officials, which provided primary and secondary data and information related to cropping systems and farming calendars, time of production and marketing opportunities, irrigation systems and infrastructure, current water management, and the impact of the newly implemented bye-law on water management.

Figure 2.3 Group discussions with farmers

2.6 Awareness Creation

A participatory workshop involving all relevant stakeholders including planners, implementers and policy makers was conducted on 18th of September 2007. The workshop provided the opportunity for all to make comments on the work and methodologies proposed by the study team. At the end of the study the stakeholders were again invited to a half-day workshop, with the aim of communicating the outcomes of the research, and of collecting constructive comments and suggestions.

3 Results and Discussion

3.1 Catchment Reservoir Capacity and Current Reserved Water

3.1.1 Reservoirs

Distribution

Within Zoba Maekel there are 74 reservoirs in total, with an aggregate water holding capacity of 67 million m^3 (Appendix 4). 11 of these are used mainly or exclusively for Asmara town water supply (Map 3.1). 46 reservoirs are used for irrigation.

49 of the total of 74 reservoirs, with an aggregate capacity of 34 million m^3, are located in the Upper Anseba Catchment including one reservoir (Deki Zeru) from Subzoba AdiTekelezan, which is in Zoba Anseba (Map 3.1). In addition to these 49 reservoirs, 3 reservoirs (AdenGoda, Quazien and Afdeyu) were built in Upper Anseba but are no more functional (Afdeyu dam was broken shortly after construction and the other two reservoirs are completely silted up).

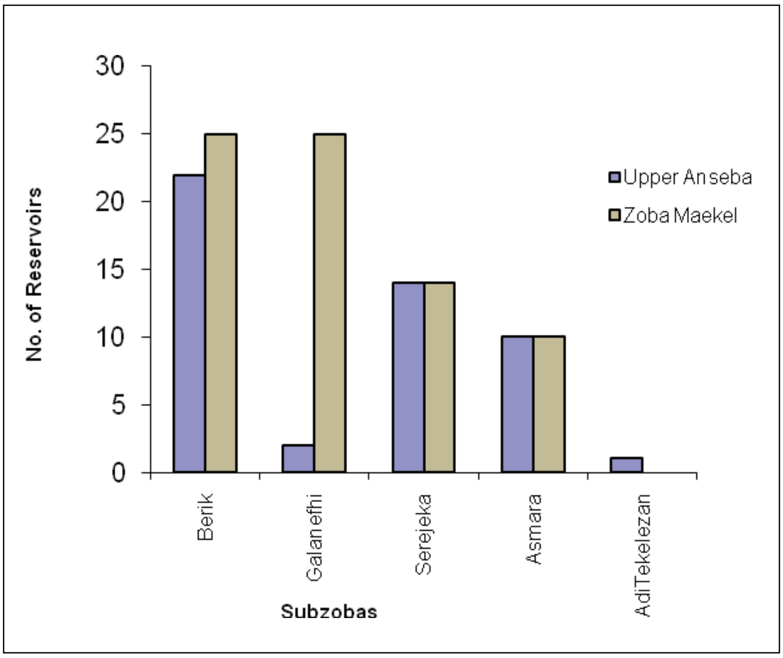


Figure 3.1 Distribution of reservoirs by Subzoba (see Map 3.1 for locations)

Reservoir Age and Implementing Agencies

The historical analysis (Table 3.1 and Figure 3.2) shows that the first reservoirs in Eritrea were constructed in the Italian colonial period, mainly for the purpose of Asmara town water supply. These reservoirs are big in size and situated in the vicinity of the town. About two-third of all reservoirs were built before independence (1991). Over half of all (55%) were constructed between 1950 and 1991, especially between 1988 and 1989 and built mainly by using labor intensive methods. Most of these reservoirs are small in size and used for livestock watering. Some have been upgraded and rehabilitated in recent years. The reservoirs constructed after 1992 were mainly for irrigation development.

Table 3.1 Distribution of reservoirs by year of construction

	Number of Reservoirs	
Year of Construction	Upper Anseba	Maekel
Before 1950	8	8
1950–1991	25	41
1992–2007	16	25
Total	**49**	**74**

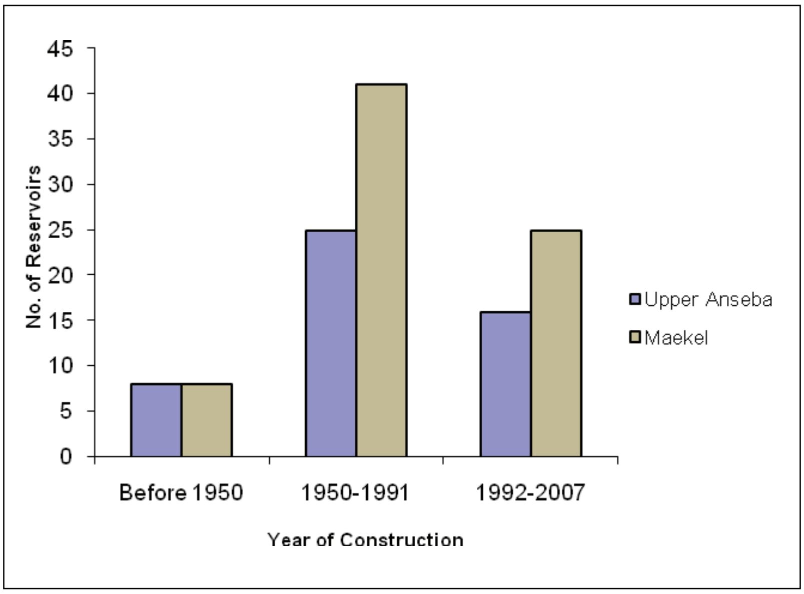


Figure 3.2 Distribution of reservoirs by year of construction

Most of the reservoirs were built by MoA (Table 3.2 and Figure 3.3), which constructed 36 of the total of 74. Seven reservoirs were constructed by MoA in partnership with other institutions such as Red Cross, ERRA, KR2, GMA, and different NGOs. 5 reservoirs were built by village communities.

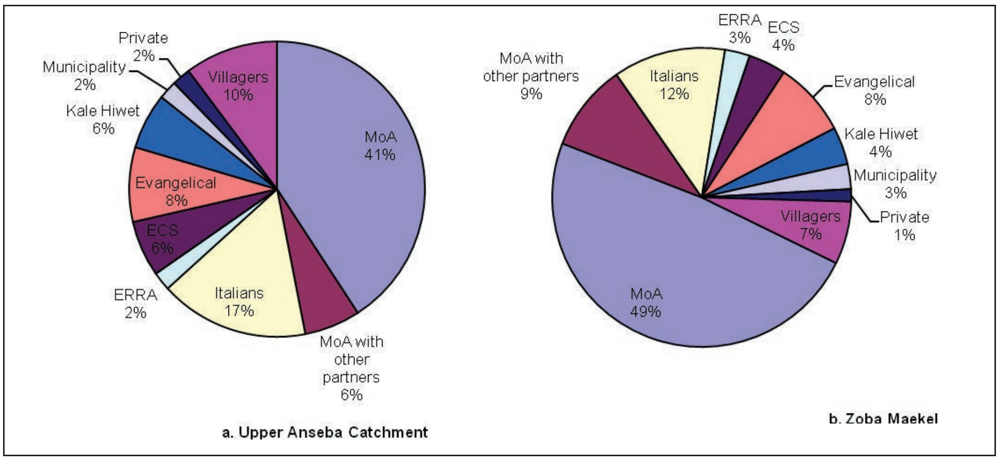


Figure 3.3 Reservoir construction by constructing agency

Table 3.2 Reservoir construction by constructing agency

Constructed by	No. of reservoirs	
	Upper Anseba	Zoba Maekel
MoA	20	36
MoA with other partners	3	7
Italian colonial administration	8	9
ERRA	1	2
ECS	3	3
Evangelical Church	4	6
Kale Hiwet	3	3
Asmara Municipality	1	2
Private	1	1
Villagers	5	5
Total	49	74

Characteristics of Dam Bodies

As indicated in Table 3.3 all reservoirs are located in the highlands at an elevation between 2000 and 2500m.a.s.l. Dam crest length varies between 45 m (Hazega-D02) and 403 m (Adi Sheka), with an average of 145 m. Dam height is between 4 m in Adi Kontsi (D-02) and 73 m in Tokor, with an average of 11 m.

Table 3.3 Basic data on the reservoirs in Zoba Maekel and Upper Anseba Catchment

	Capacity (Million m^3)		Dam crest length (m)		Dam height (m)		Elevation (m.a.s.l)		Catchment area (ha)	
	Maekel	UAC	Maekel	UAC	Maekel	UAC	Maekel	UAC	Maekel	UAC
Average	0.87	0.7	145	144	11	10	2247	2281	806	850
Minimum	0.04	0.04	45	45	4	4	2040	2125	15	15
Maximum	26	14	403	403	73	73	2474	2474	14,136	14,136

UAC: Upper Anseba Catchment

90% of the dams are earth fill constructions (Table 3.4) because this method is cheaper and relatively easy to construct. Two dams (Hayelo Gheshnashm and Laugen Adi Hamushte) are rock fill; excessive seepage is observed in these 2 reservoirs, so that small embankments have been built downstream to collect the water and make it available for irrigation and other purposes. 5 dams are built as concrete or masonry structures.

Table 3.4 Types of dams in Zoba Maekel and Upper Anseba Catchment

Dam type	Zoba Maekel	Upper Anseba
Earth fill	67	43
Rock fill	2	1
Masonry or concrete	5	5
Total	**74**	**49**

Figure 3.4 Adi Bidel concrete dam

Catchment Areas

The catchment areas were delineated with the help of a DEM in ArcView 3.3 GIS software. Their size ranges from 0.15 to 141 km^2. Seven (14%) of the 49 reservoirs in the upper Anseba Catchment have catchments of less than 1 km^2. These are Tselot, Adi Merawi, Tsaeda Emba, Adi Abeyto, Adi Kontsi (D-03), Adi Bidel and Mesfnto. 35 (70%) of the reservoirs have catchment areas between 1 and 10 km^2. In the rest of Zoba Maekel, there are two reservoirs with catchments smaller than 1 km^2 in addition to the 7 reservoirs located in Upper Anseba. Finally, 11 reservoirs have catchments between 10 and 40 km^2, and one has a catchment of over 100 km^2 (Table 3.5).

Table 3.5 Distribution of reservoirs by size of catchment area

Catchment area (km^2)	Number of reservoirs	
	Upper Anseba Catchment	Maekel
< 1 km^2	7	9
1-10 km^2	35	54
> 10 - 40 km^2	6	10
>100 km^2	1	1
Total	**49**	**74**

The relationship between catchment size and reservoir capacity is weak, especially relating to medium and small sized reservoirs (Figure 3.5). The biggest town water supply reservoir in terms of capacity is Mai Nefhi with 26 million m^3, and it has the second largest catchment (8.7 km^2). The reservoir with the biggest catchment is Toker with its 14 million m^3 capacity; however, there are a number of smaller reservoirs within its catchment storing a considerable amount of the runoff.

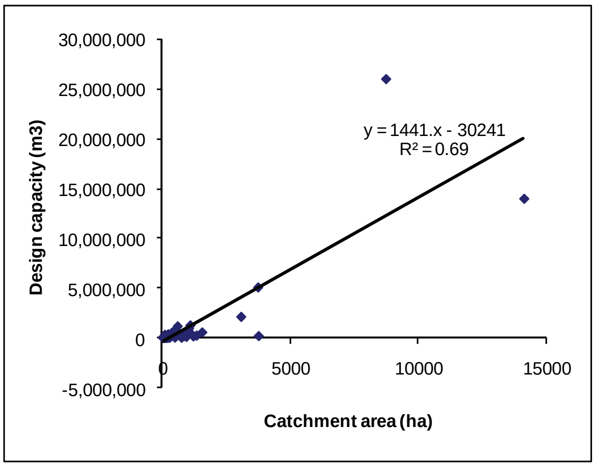


Figure 3.5 Relationship between catchment area and reservoir design capacity

3.1.2 Reservoir Capacity

Efficient water management and sound reservoir planning and management are hindered by inadequate knowledge of storage volumes. This study therefore collected the design capacity of all reservoirs from secondary data within government administration. In addition to this, current reservoir capacity of selected reservoirs was also determined. For this purpose, a dam re-survey was carried out.

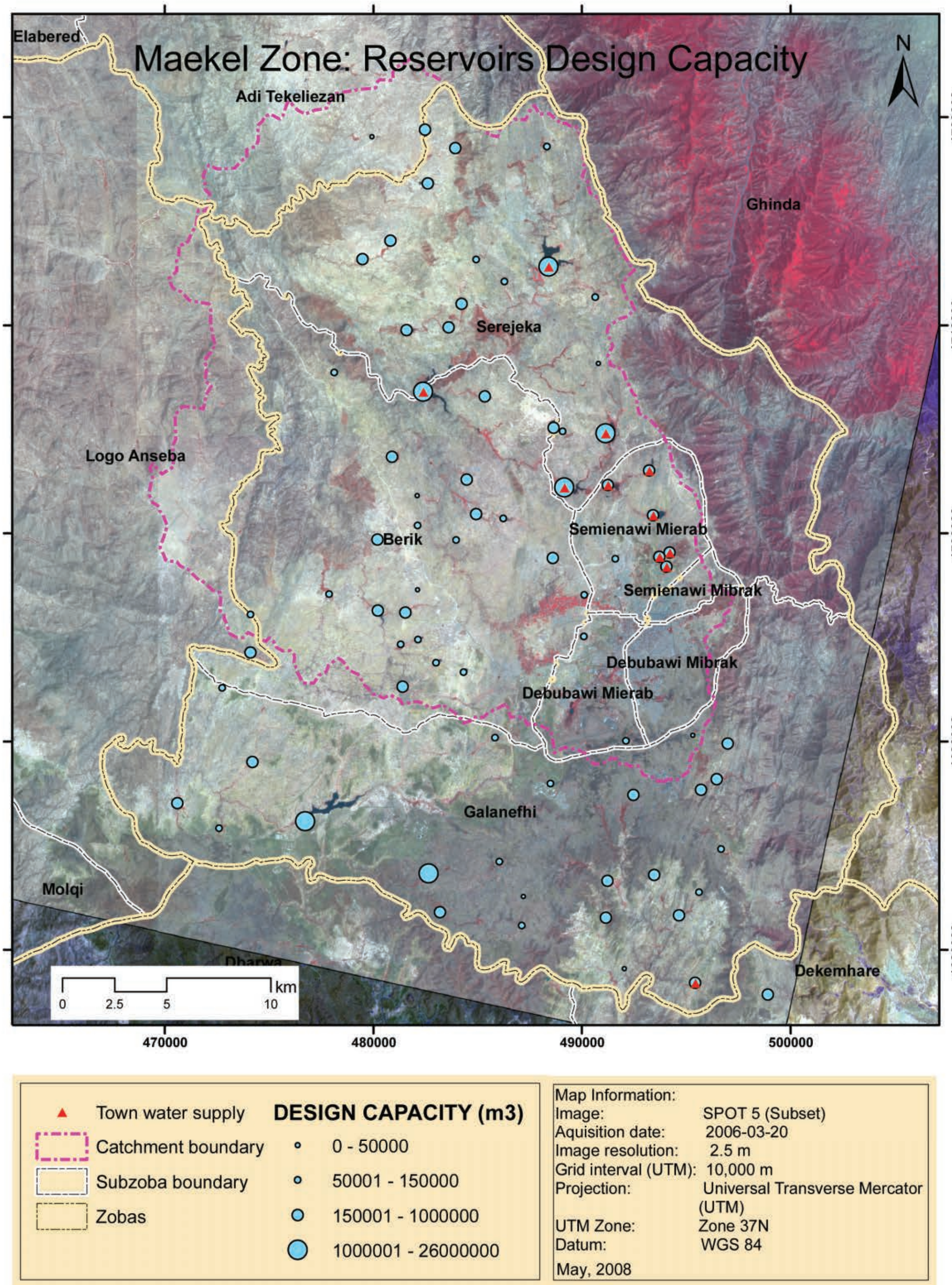
Design Capacity, Current Capacity, and Current Water Volume

The design capacities are presented in Tables 3.6 and 3.7, and in detail in Appendix 4. They range from 40,000 m^3 (Adi Keih and Hazega dams) to 26 million m^3 (Abardae-Mai Nefhi dam). Average design capacity is 850,000 m^3 (Map 3.1). The aggregate design capacity of all reservoirs is 67 million m^3, of which 32 million m^3 is stored in Upper Anseba Catchment. As most of the reservoirs are more than a decade old, it can be assumed that their capacity has significantly decreased due to sediment deposition over the years. In order to assess this decrease and establish current storage volume, a detailed survey of nine selected reservoirs was carried out and current reservoir capacity and water volume were determined by a bathymetric survey. The results are presented in Table 3.6.

Table 3.6 Current Storage Capacity, Current Water Volume, and Design Capacity of selected reservoirs

Reservoirs	CWLA (m^2)	CWLV (m^3)	SLA (m^2)	SLV (m^3)	DSC (m^3)	UC (m^3)
Hayelo	26,049	69,551	138,573	650,043	1,000,000	
Zagr	18,943	41,963	42,684	81,926	150,000	
Embaderho	86,033	166,306	136,000	314,833	330,000	
Tseazega	111,936	214,272	200,239	353,803	230,000	453,420
Ametsi	25,522	99,303.8	44,909	118,720	180,000	
Adesfeda	74,710	153,912	116,905	294,749	200,000	365,755
Laguen	43,633	114,202	232,217	1,031,791	1,200,000	
Lamza	15,870	25,612	93,674	442,780	500,000	
Himbrty	39,034	66,208	118,076	337,829	330,000	450,000

CWLA-Current water level area; CWLV-Current water level volume; SLA-Spillway level area (m^2); SLV-Spillway level volume or actual reservoir capacity (m^3); DSC-Design (original) storage capacity; UC- upgraded capacity (capacity gained after the height of the dam was increased).



Map 3.1 Estimated design capacities of surveyed reservoirs

The bathymetric survey made it possible to make a rough estimate of the sediment deposition within the reservoirs, by deducting current storage capacity from design capacity. The results are presented in the following paragraphs.

Siltation

In Eritrea, 15% of the design capacity is provided for sediment accumulation. Under ideal conditions, the useful lifespan of the medium and small dams in the country is between 15 to 20 years, but it is estimated that this could be reduced to five years or less if siltation is severe (Negassi, et al., 2002). Siltation rates of up to 30% of the design capacity over a period of about 40 years have been recorded in some reservoirs in Masvingo Province in Southern Zimbabwe (Zirebwa and Twomlow, 1999).

The present study clearly shows that many reservoirs have siltation or sedimentation problems, although it is difficult to present quantitative data. Reservoirs with observable siltation problems in Zoba Maekel / Upper Anseba are Adi Habteslus, Himbrti Chea, Adi Hawsha, Laugen, Adi Gombolo and Mesfnto. For example, Mesfnto is a small reservoir with 60,000 m^3 capacity situated in Subzoba Serejeka. Its catchment of 1 km^2 is dominated by moderately steep slopes prone to erosion, and only partially treated with soil conservation structures. During field survey for this study, villagers from Msfnto reported that the reservoir capacity had been decreasing over time and that they could not irrigate twice a year as they used to do. This is a pity because they have experience in irrigation and their management system seems to be efficient. At present, they grow potatoes during summer by irrigation using dam water, and maize and garlic during the rainy season.

Figure 3.6 Reservoir with high sediment load (offsite effect of erosion), Mesfnto

This study used two different approaches for calculating siltation volumes and rates, which were reservoir re-survey and catchment characterization. Both methods are described in Chapter 2 of this report. They were applied to 9 selected reservoirs within Upper Anseba.

Reservoir Re-survey

As Table 3.7 shows, the specific sediment yield (SSY) for the 9 selected reservoirs lies between 132 and 1846 $m^3/km^2/yr$ with a mean value of 703 $m^3/km^2/yr$. The mean sediment yield (SY) varied from 948 to 12,939 m^3/year with a mean annual deposition of 4,600 m^3/year. These figures thus cover a wide range of values, but can be reconciled with the findings from Northern Ethiopia (Tamene et al:2006). The values for Hayelo Gheshnashm dam are much higher relating to both SY and SSY; it is suspected that the figure for the design capacity of this dam was incorrect; otherwise the huge storage loss within two decades is difficult to explain. At the other end, the volume of sediment in Embaderho dam is very small. This is attributed to desilting done there in 2002. The actual storage capacity was found to be 357,000 m^3 from a survey done after desilting. Therefore the silt load of this dam has accumulated within five years and should be interpreted accordingly.

Table 3.7 Reservoir sediment deposition derived from Bathymetric Survey data analysis

Reservoirs	Design capacity (m^3)	Current capacity (m^3)	Catch-ment area (km^2)	Age (yr)	SV (m^3)	SY (m^3/yr)	SSY (m3/km^2/yr)
Hayelo	1,000,000	650,043	10.32	11	349,957	31814	3074
Zagr	150,000	81,926	2.84	24	68,074	2836	999
Embaderho	330,000	314,833	2.40	16*	15,167	948	397
Tseazega	453,420	353,803	37.62	20	99,617	4981	132
Ametsi	180,000	118,720	1.66	20	61,280	3064	1846
Adesfeda	365,755	294,749	7.86	20	71,006	3550	452
Laguen-AdiHamushte	1,300,000	1,031,791	10.94	13	168,209	12939	1184
Lamza	500,000	442,780	8.52	22	57,220	2601	305
Himbrti	450,000	337,829	11.29	19	112,171	5904	523

SV-sediment volume; SY-sediment yield; SSY-specific sediment yield

*Embaderho dam was built 1991 years ago it was desilted in 2002 (5 years before this present survey).

Catchment Characterization

This second method used for sediment yield estimation is based on the model by DFID (2004). The results are presented in Table 3.8. They, too, show a high variation of sediment yields, which extend from 262 to 1769 t/km^2/year, with an average of 856 t/km^2/year. Size and range of variation are high compared to regional datasets from other countries; for example, DFID (2004) puts African and world median SSY values at 299 and 252 t/km^2/year respectively. On the other hand, the values established by the present study are in agreement with those obtained in Tigray (Nothern Ethiopia) by Haregeweyn et al (2006), who reports SSY values between 237 and 1817 $t/km^2/yr$ with an average of 909 $t/km^2/yr$. Moreover, average annual sediment yields within the same order of magnitude (598 t/km^2/year for the whole Anseba Basin, and 782 t/km^2/year for all the major river basins in Eritrea) have been mentioned in earlier studies done in Eritrea (MoLWE, 1998).

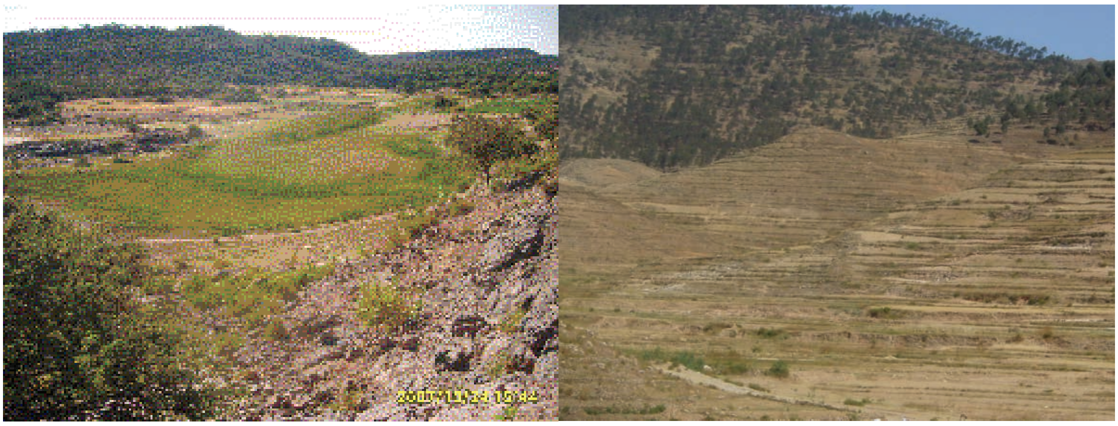


Figure 3.7 Major catchment characteristics of the selected reservoirs: Terraced farmland or Eucalyptus plantations

Table 3.8 Parameters used for the calculation of sediment yield

Reservoirs	Parameters used						Sediment Yield (t/km²/year)
	Area (km²)	MAP (mm)	Slope	SASE (score)	STD (score)	VC (score)	
Hayelo Gheshnashm	10.35	434	0.063	10	10	15	262
Zagr	2.84	434	0.083	20	10	40	1275
Embaderho	2.4	461	0.097	20	10	40	1376
Ametsi	1.66	452	0.058	10	10	40	636
AdiAsfeda	7.86	463	0.016	20	20	40	1769
Lamza	8.52	328	0.047	10	20	10	298
Laugen AdiHamushte	10.94	348	0.022	20	20	15	830
Himbrti Gomini	11.29	348	0.037	10	20	15	359

Sy-sediment yield; Area-Catchment area; MAP-Mean annual precipitation; Slope-River slope from the catchment boundary to the dam; SASE-Signs of active erosion; STD-Soil type and drainage; VC- Vegetation condition

Table 3.8 shows the parameters used for characterizing the catchments as a preliminary step to assess sediment yield. The Table shows 8 catchments only, excluding Tseazega catchment, which was difficult to characterize as it has several small reservoirs upstream which retain a significant proportion of runoff. From the eight remaining reservoirs, Himbrti Gomini has the largest catchment and Ametsi the smallest one. The MAP is higher in subzobas Serejeka and Berik as compared to Galanefhi. The score of SASE is higher in catchments with lower vegetation cover and in places with more human interference such as settlements.

Figure 3.8 Former gold mining site and possible source of silt for downstream reservoir, Adi Asfeda

The high values and and high degree of variation of sediment yields within the study area can be attributed to differences in land use and land cover, drainage density, and other physiographic characteristics of the catchments. Current land and water management practices also differ from one catchment or sub-catchment to the other. For example, it was found that at some sites farming was practiced up to the edge of the reservoir (Fig. 3.9), and signs of serious erosion have been observed upstream of many reservoirs. Neglected or abandoned land is another source of erosion and thus siltation, such as for example the former gold mining area of Adi Asfeda (Fig. 3.8), a typical example of neglect.

The results obtained from the bathymetric survey could be compared with those derived from the catchment characterization, if the figures were converted to the same dimension (both in $t/km^2/year$). In order to make this conversion, one would have to know the bulk density of the deposited sediments, which was not part of the study. Moreover, if such a conversion is made, it should be kept in mind that the bathymetric survey and the catchment characterization measure the same phenomenon – sediment yield – but from a different perspective which may result in different outcomes: the bathymetric survey indicates the sediment yield on the basis of the sediment accumulated in a reservoir. The catchment characterization gives the sediment yield from the catchment, and this may be more than what is found in a specific reservoir, as some of the water, holding sediments, typically spills over the dam (all dams have spillways) in any rainy season. It can therefore be hypothesized that the SSY values derived from the catchment characterization equation are too high for any given reservoir. This needs further investigations, though. Also the sediment values should be confirmed by further investigations.

Figure 3.9 Cultivated plots next to the reservoir, Adi Asfeda

Current Capacity of Reservoirs

It is difficult to present precise figures for the current capacities of the reservoirs, as there are many factors that need to be considered in detail, and the original design capacity figure may also be approximate rather than precise. The figures presented in Tables 3.6 and 3.7 above were used to illustrate storage loss through sedimentation by showing design capacity and current storage volume for each dam graphically. The result is presented Figure 3.10. Based on the sample of the nine reservoirs, 11- 45% of the design capacity of the reservoirs has been filled up with sediment, mostly within a time span of two decades as most of the dams were built within this period. The average value is 23%. This corresponds to 0.5 - 2 % storage capacity loss per year, a figure that can be well reconciled with those given by Pimentel et al (2004), who estimated that 1% of the storage capacity of the world's dams was lost due to siltation each year (cited from Economist, 1992).

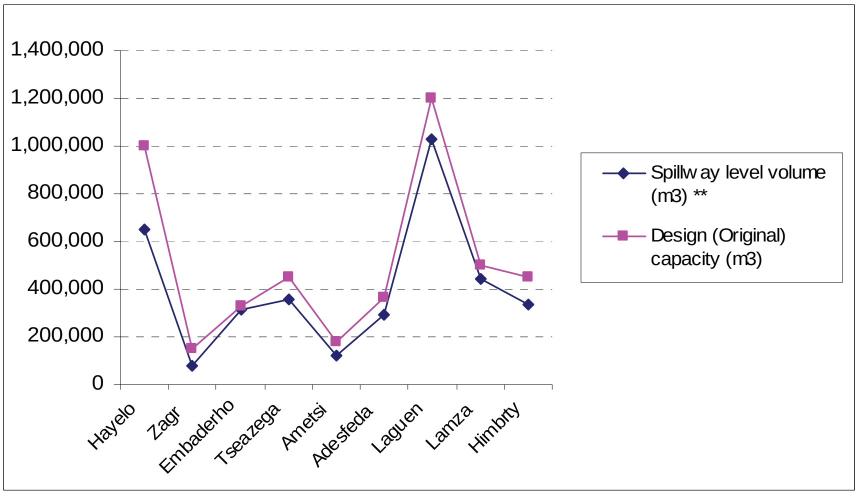


Figure 3.10 Design (original) versus current storage capacities of selected reservoirs

3.1.3 Catchment Water Balance

After estimating storage losses due to siltation, we now turn to the question of how much water flows into the reservoirs. In order to answer this basic question for water and irrigation management, catchment water balances were established based on the different variables, and differentiated in space. Catchment water balances are difficult to establish as many factors have to be considered over longer periods of time, especially relating to rainfall which is highly variable in the study area. In many parts of the world, models were therefore developed in catchments with long time meteorological records and with support of remote sensing information.

Unfortunately, the reality for most catchments in Eritrea including Upper Anseba is different, as many of the parameters crucial for water balance calculation are not available. Meteorological data are inconsistent, intermittent, leave gaps in space and are unreliable in many cases. The poor data record is rooted in financial problems and in poor institutional capacity.

Thus, the water balance presented in the following paragraphs was carried out in ungauged or insufficiently gauged catchments, which represents the situation found in the large majority of all catchments in the country. The following figures are therefore indicative, but can still give decision makers and planners an idea of the water resources potential in Upper Anseba. But the results from this study are preliminary and should be confirmed by future studies.

The basic model of a water balance equals input (precipitation, run-on) to outputs or losses (runoff, evapotranspiration, infiltration, storage):

$P = R + ET + F$

Where P = precipitation
R = runoff
ET = Evapotranspiration
F = Infiltration

The input parameter in Upper Anseba as a headwater catchment is precipitation only. There is no ice-melting source nor is water flowing into the area from other catchments. The output is the amount of water that flows out of the catchment, plus evapo-transpiration, plus water that flows into groundwater. For reasons of simplicity, the amount of water retained in the soil is taken to evaporate or to join groundwater reserves.

Precipitation

Precipitation in Upper Anseba, as in most parts of the country, is rainfall. Data were obtained from five stations located at AdiNfas, Embaderho, Hazega, Serejeka, Tseazega and Asmara. These stations were selected because of their relatively long period of records and they reasonably well spread over the whole study area. Each rain gauge represents an area of about 120 km². The data set used in this analysis covers the years from 1997 to 2007, including two years with missing records (2002 and 2006). Asmara has a longer record (1988-2007).

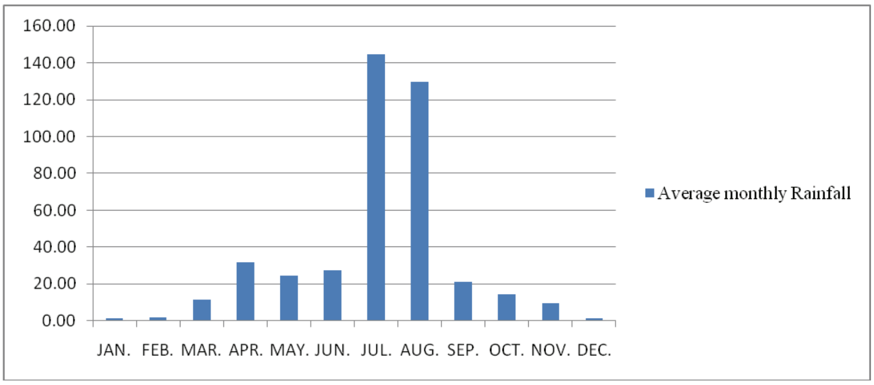


Figure 3.11 Mean monthly rainfall of Asmara, 1988-2007

The histogram with the rainfall data of Asmara (Fig 3.11) shows that precipitation concentrates in the months of April to September. Around 65% of the annual amount is received in July and August alone on average. The period generating runoff and hence has a potentian for storage is rather limited.

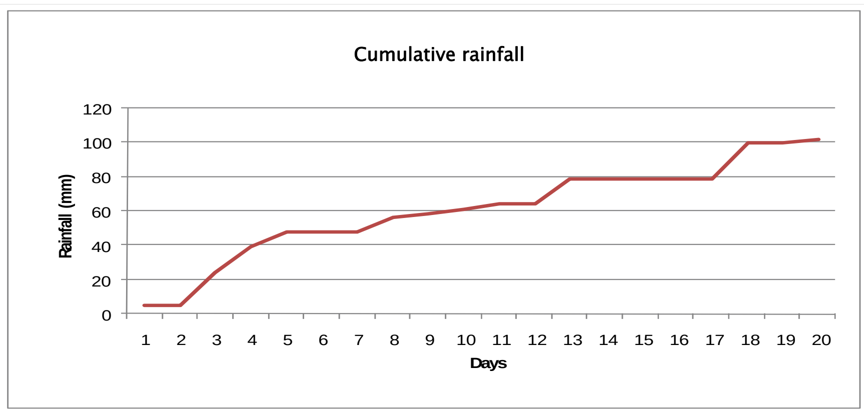
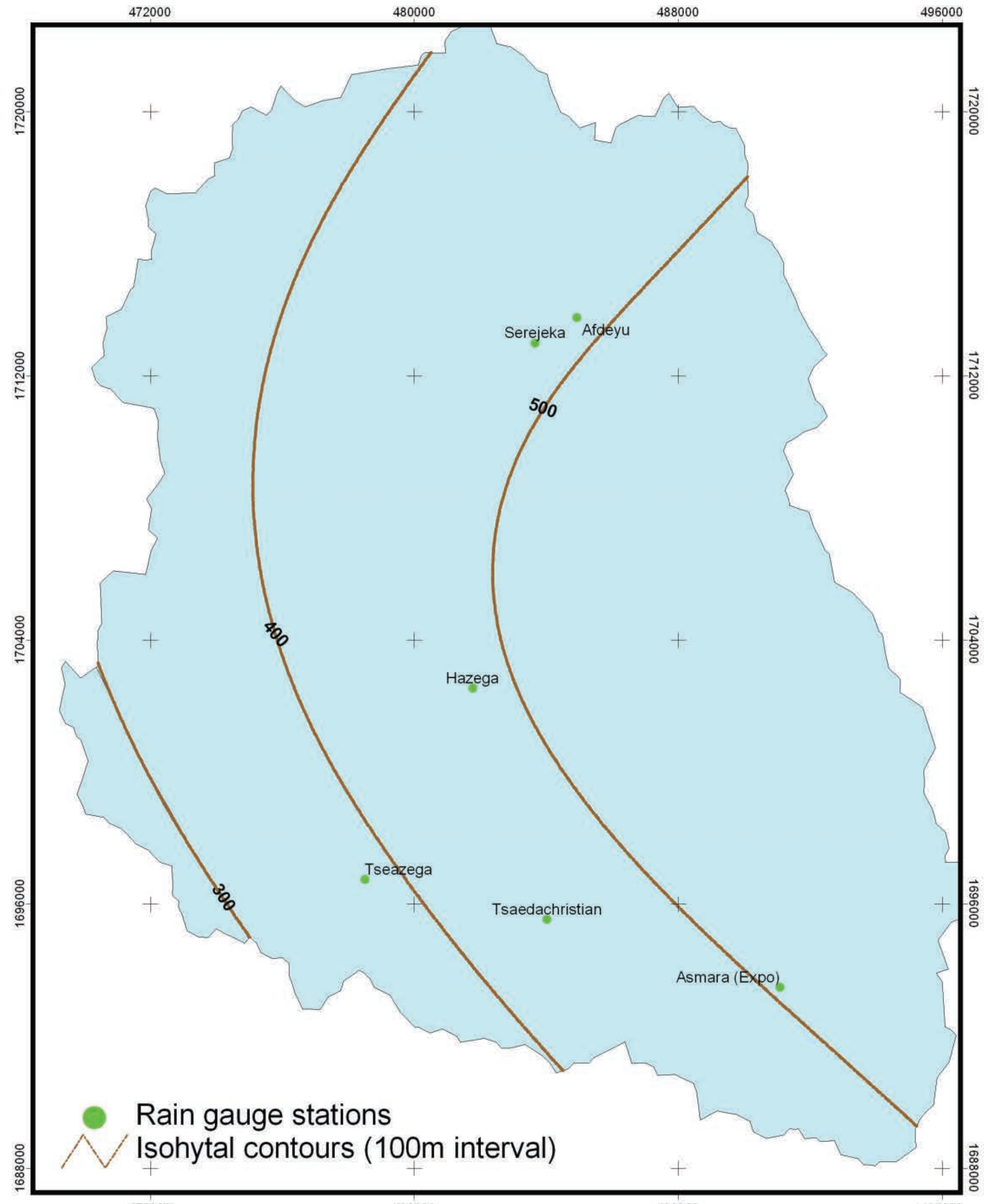


Figure 3.12 Cumulative daily rainfall in Serejeka for July (1997-2007)

Figure 3.12 presents a daily cummulative graph of rainfall from Serejeka rain gauge for the month of July. The figure shows some steep sections indicating high rainfall. The horizontal sections represent series of subsequent days without rainfall.



Map 3.2 Isohyetal Map of Upper Anseba Catchment

Input: Rainfall

The amount of rainfall in the catchment was calculated using the records from the 6 raingauges mentioned above, i.e. including Asmara. Ten year averages were used to calculate the average annual rainfall for each station (Table 3.9), which in turn was used to produce an isohyetal map (Map 3.2) for Upper Anseba. Based on the map, the average yearly rainfall in the Catchment was found to represent a volume of about 289 million m^3 of water.

Table 3.9 Average yearly rainfall data 1997 - 2007

Year	Station					
	Tsaedachrstian	Tseazega	Hazega	Serejeka	Afdeyu	Asmara
1997	608.8	555.6	604.0	580.5	643.0	688.5
1998	412.0	332.8	329.0	494.4	598.7	562.4
1999	359.9	258.6	327.8	505.8	649.7	494.3
2000	499.6	351.2	531.7	487.0	500.6	572.9
2001	587.6	568.0	823.8	557.2	517.2	616.4
2002	NA	NA	NA	NA	NA	374.9
2003	366.9	278.6	422.1	397.1	405.6	399.1
2004	301.1	292.4	296.1	413.7	430.8	345.5
2005	498.6	378.1	541.2	587.5	324.0	509.9
2006	NA	NA	NA	NA	NA	544.4
2007	409.2	401.3	473.6	349.0	348.5	443.9
Average	449.3	379.6	483.3	485.8	490.9	504.7

NA- Data not available

Evaporation

Evaporation measurement is commonly based on pan evaporation. This instrument is limited to measure evaporation from an open water body. The amount of evaporation from different types of land use and transpiration from plants cannot be quantified directly.

Nevertheless, data from the pan can be used for calculating evapotranspiration: Several methods were developed based on different models for estimating evapotranspiration from climatic data. Equations such as those of Thornthwaite (1931), Thornthwaite (1949), Turc (1954) and Blaney and Criddle (1950) are temperature-based methods. The simplest equation, developed by Thornthwaite (1931), equates the ratio of annual precipitation to evaporation with the ratio of precipitation to mean annual temperature. Blaney and Criddle's (1950) equation incorporates an additional variable k (empirical crop factor) alongside temperature. Generally, temperature-based evaporation estimation equations are still widely used and have been found to be relatively accurate (Jones, 1997). But since temperature is not always the dominant and only factor for evaporation, and since the relationship between temperature and evaporation is not linear (Jones, 1997), all these models can only provide proxy values for evaporation. The Blaney/Criddle model results in an average evapotranspiration of 100 mm per month, with the exception of the rainy period (85mm per month) (Figure 3.13).

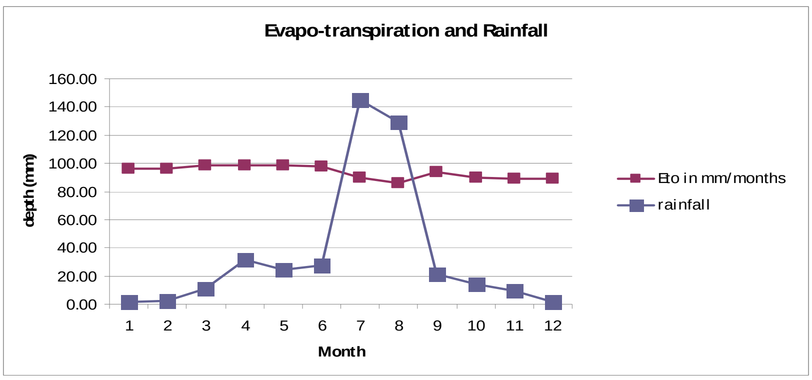


Figure 3.13 Potential evapotranspiration and rainfall in Upper Anseba Catchment

Due to the shortcomings of temperature-based equations, more comprehensive models were developed such as the combined formula by Penman. Section 3.2.1 of this report, which deals with irrigation scheduling, presents values derived from a similar complex formula (CROPWAT). According to this formula, Asmara has a daily evaporation of 6.6 mm during March and April and of 3.8mm/day in August. The annual average for Asmara is 5.3mm/day, and for Afdeyu, which lies at a higher altitude, the figure was 4.5 mm/day (see Tables 3.17 and 3.18 in section 3.2.1).

Whatever model is used, precipitation in July, August and September is higher than potential evapotranspiration. This is thus the period in which soils are refilled and run off occurs (Figure 3.14). The latter is important for dams.

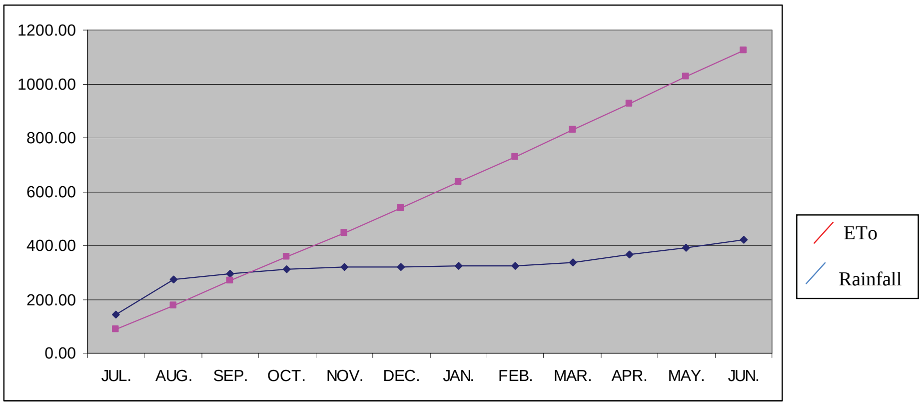


Figure 3.14 Cumulative rainfall and potential evapotranspiration, based on Asmara Meteorological Station (1988-2007)

Runoff

Runoff is the amount of water that flows to the river channels on the surface and/or through base flow. It represents the surplus of rain over evaporation and infiltration. The amount of runoff, sometimes called the surface yield of a catchment depends on many factors including land cover, land use, soil, topography, and rainfall characteristics.

This study estimated runoff within Upper Anseba by using water level data collected daily at the Toker reservoir dam. The water level in this reservoir indicates the amount of water retained by the dam. Measurements are taken daily. Since the catchment of the Toker dam is not big and the rainfall-runoff lag is short, these daily water level records can be taken to estimate runoff into the reservoir.

The problem is that there are several small and medium size dams upstream of Toker which may hold back some of the runoff. To eliminate this problem, the calculation was limited to the rainy season when the upstream dams were full, which to some extent ensures that the yield from the whole Toker catchment makes its way to the dam.
Calculations were based on the following model:

$I - O = \Delta S,$

$I = \Delta S + O$

Where: I is Input water

O is Output which is discharged water and evaporation & leakage

ΔS is change in storage in the dam

$I = Rv + Pw$

$Rv = I - Pw$

Where Rv is volume of water from runoff of the catchment
Pw is rainfall on the dam's reservoir water surface
C = Rv/Pd
Where C = runoff coefficient
Pd = isohytal average precipitation
Pd = Σ (Wi * Pi)
Where Pd is isohyetal average precipitation
Pi average precipitation between the two consecutive contour values
Wi = Ai / A
Where Ai is area between two adjacent isohyets
A is total area of the catchment
i is the number of isohyetal polygons

It should again be noted that the result of this calculation must be taken as indicative. Sources of errors include the paucity of raingauges and the relatively short duration of records considering the semi-arid climate. Thus a 20% margin of error in rainfall was built into the estimate.

Table 3.10 Change in storage and runoff coefficient for the Toker Catchment

Date	Pd	Pw	E	Q	ΔS	C
1 – 5 of July	9,451,200	7060.4	1861.4	50000	656,000	0.07
6 – 12 of July	8,248,800	9061.7	2425.7	60000	576,000	0.08
13 – 26 July	15457406	19270.8	6054.2	130000	1,172,902	0.08
1 – 9 August	10397612	5833.8	6475.5	90000	1,573,000	0.16
10 –17 August	3231469	10888.9	5127.7	80000	513,090	0.18
17 – 25 August	6943548	9223.6	6825.7	80000	1,912,360	0.29

The results (Table 3.10) show that runoff varies over the rainy season. The runoff coefficients range from 0.07 to 0.29. In the early days of the rainy season, the coefficient is low, i.e. the catchment yield is small. This is so because some of the water is retained in the upstream small dams and also because there is high infiltration until soil saturation is reached. As the upstream ponds gradually fill up andbase flow in the catchment increases, runoff increases. On average the runoff coefficient in the Toker catchment can be estimated to be about 0.14. This result should be used only for the rainy season. For rainfall during the dry season (April to June), the lowest value in the Table should be used, resulting in a coefficient of 0.07. The average yearly runoff coefficient could be about 0.12, but this is an informed guess.

This figure for the annual runoff coefficient is close to the maximum of what other research has found. In Afdeyu, a gauged catchment also located in Upper Anseba, the runoff coefficients covered a range from 0.054 to 0.129 (Burtscher 2003). He attributed the low runoff coefficient in this catchment to the extensive soil and water conservation campaigns carried out in that catchment. The Toker catchment has only sporadic soil and water conservation, which may help explain why runoff is on the upper end of the values given for Afdeyu.

In order to determine the amount of runoff for the whole of Upper Anseba as precisely as possible and hence differentiate key variables in space, the isohyetal map was used to divide the region into several rainfall zones and determine their surface area. In addition to this, the runoff coefficient was differentiated for the rainy and for the dry season, using a value of 0.08 for the latter and a value of 0.17 for the former. Based on these input data, total runoff within Upper Anseba is about 41 million m^3 of water per year, with a margin of error of ±4 million m^3 (Table 3.11).

Table 3.11 Table showing runoff volume for the Upper Anseba Catchment

Rainfall (m)	Area (m^2)	Runoff Coefficient		Runoff volume (m^3)
0.30	13,413,975	0.14 X 70%	0.07 X 30%	478,878.9
0.42	138,259,221	0.14 X 70%	0.07 X 30%	6,910,195.9
0.54	265,086,926	0.14 X 70%	0.07 X 30%	17,034,485.9
0.66	215,996,681	0.14 X 70%	0.07 X 30%	16,964,379.3

The result of the above model was checked by introducing land use into the calculus, known to be a key factor for runoff. A basic land use map was prepared, featuring eight major land use categories. Each category was assigned with a specific runoff coefficient based on expert estimations. Settlements and wetlands were given a high coefficient and so were barren and forested areas. Farming areas with rain fed and irrigated crops were given low values due to their location in flat areas and their deeper soils. The resulting runoff coefficients are shown in Table 3.12.

Table 3.12 Expert estimation of different Land Use Coefficients

NO.	Land use	Estimated Coefficient
1	Forest	0.12
2	Rain fed (Agriculture)	0.07
3	Settlement	0.15
4	Water bodies	1.00
5	Wet land	0.20
6	Open shrubs	0.10
7	Irrigated land	0.08
8.	Bare soil	0.13

Source: Questionnaire filled by experts

These specific coefficients were then upscaled to the whole Upper Anseba Catchment, by overlying the land use map with the isohyetal (rainfall) map presented above. Using the area calculated from the intersection of the two maps (see map 3.3), the specific water yield or runoff from each land use category was calculated. It gave an average annual runoff coefficient for Upper Anseba of 0.115, or 11.5%, which can well be reconciled with the values used before (0.08 / 0.17 for the dry and the rainy season, respectively).

Groundwater Reservoir

Water infiltrating into the soil is either evatranspirated through vegetation, joins a surface river as base flow, or trickles down into ground water. In most cases groundwater flow is slow so that the water is literally stored in the ground. In some cases however, and especially in the highlands, the water follows major fractures and swiftly moves away from the place of re-charge. The geology of Upper Anseba is dominated by meta-volcanic rock types, which have gone through successive tectonic processes. It is therefore not easy to understand groundwa-ter flow in this area, and not much research has been carried out on the topic in Eritrea. In short, bed rock aquifers behave considerably different from those in sedimentary deposits.
Among the few studies carried out in the crystalline rock of the central highlands are those made on groundwater recharge by Haile (2005) and Solomon (2003). Both used the

mass balance method to estimate recharge and came up with similar figures relating to rate of recharge. According to Haile (2005), this rate is 8% in metavolcanic rocks, i.e. greater than in basalts where it is 6%, and in granites, where it is 3%. These results are in agreement with the water balance done in the present study, where in the rainy season, evapotraspiration was calculated to be around 75% of rainfall, runoff around 14%, leaving 11% for groundwater recharge. This is close to the 8% mentioned by Haile (Upper Anseba is dominated by metavolcanic rock). In the dry season, evapotraspiration is 90% or higher, runoff as low as 7%, and groundwater recharge thence very low (3% or less).

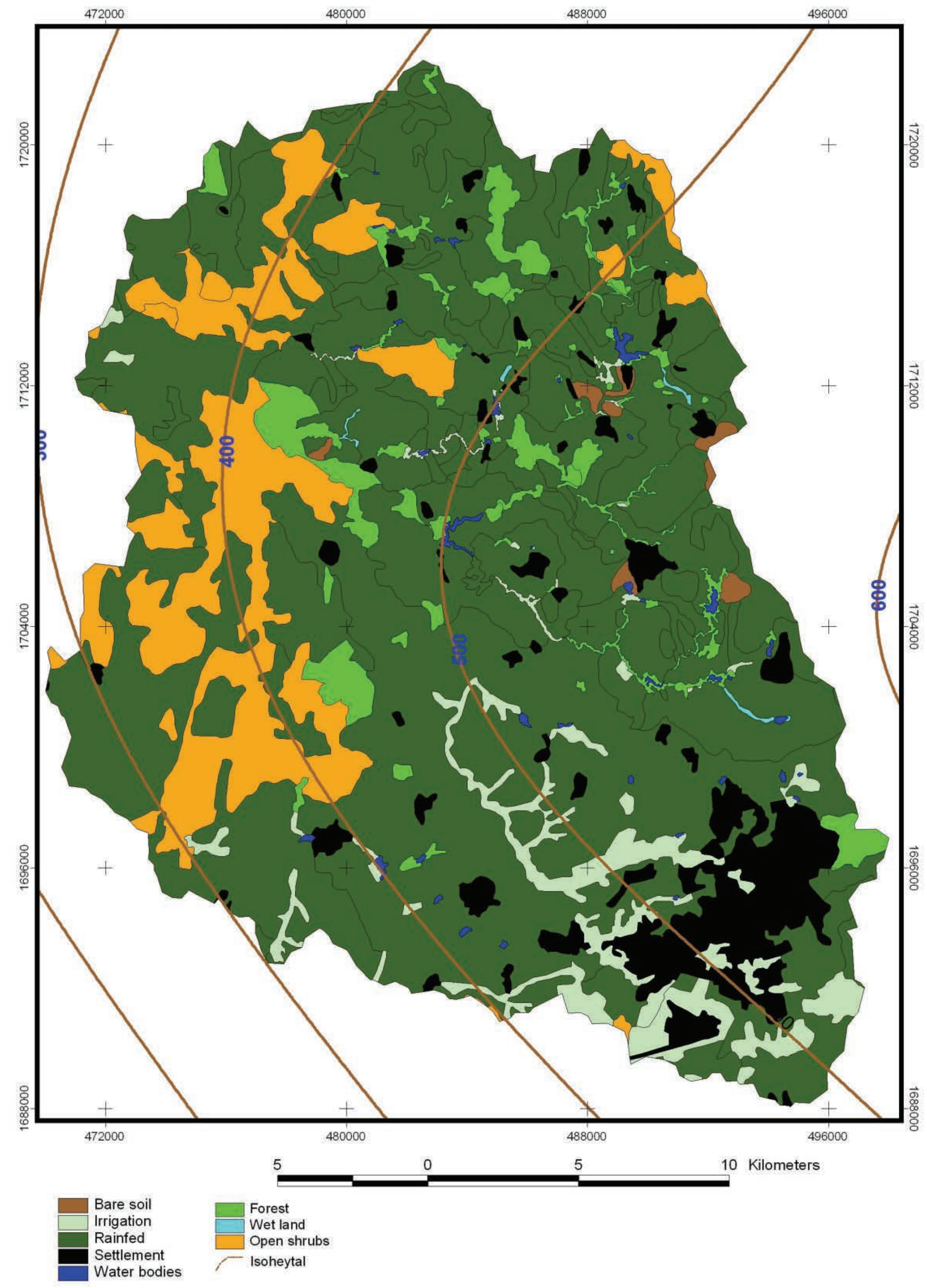
But overall, it is difficult to discuss groundwater recharge figures without including flow (velocity and direction) of groundwater. Both of the studies quoted above did not consider flows and were thus of limited use to planners and practioners in water development. Following the general morphology of Upper Anseba, groundwater flows should gravitate towards the direction of the steepest slope, i.e. towards Northwest. However, fractures created by tectonic effects may alter the direction of the flow; but it is important to note that groundwater reserves of Upper Anseba might be moving out of the catchment due to the high flushing rate resulting from difference in altitude (Haile, 2005), even though the speed at which this happens is not known to date.

Nonetheless, the above groundwater recharge rates give an indication of the amount of water that is transferred from surface to groundwater. If we assume that the rate of recharge is uniform over the whole Upper Anseba area, then the yearly groundwater recharge amounts to roughly 23 million m^3 per year. For the time being, it can safely be assumed that this amount of water is a potential groundwater reservoir, provided that groundwater movement is slow.

Surface Water Reservoir

As we have seen, there are 49 reservoirs in Upper Anseba Catchment. They are fairly well distributed over the whole catchment, but leave a gap in the central western part which is drained by Maibela River. This river is contaminated by the sewerage system of Asmara. Apparently, this water is not suitable for use as long as it is untreated.

The total potential capacity of the reservoirs was shown to be 32 million m^3 of water, but 23% of this volume was lost to sediments, leaving a reserve capacity of about 24.5 million m^3. This represents close to 70% of total annual water yield resulting from runoff (41 $\pm$ 4 million m^3) that is provided by rainfall over the whole Catchment. The reserve capacity could thus still be increased by a maximum of about 30% to exploit 100% of the annual water yield. The additional capacities would have to be shared between irrigation and rural use on the one hand, and urban (Asmara) uses on the other, as the above calculation are based on the whole catchment. Increased reservoir capacities would also mean that less water flow out from Upper Anseba. This could create problems of water supply in downstream areas. Moreover, plans for increasing reservoir capacities should be based on subcatchment water yields, and the potential for such increases should be established for each reservoir individually, as the share of the water already stored may vary considerably between different reservoirs. Finally, the area below Mai Bela River should not be used as a catchment cum reservoir, at least not before the water of this river is treated.



Map 3.3 Intersection of land use and rainfall (Isohyets), Upper Anseba

3.2 Use of Reserved Water

3.2.1 Agricultural Use

Irrigation

In Zoba Maekel 46 of its 74 reservoirs are used for irrigation. 31 of them are class one reservoirs designed for irrigation, domestic purposes and livestock watering (Table 3.13 and Appendix 4). From these, three reservoirs (Adisheka, Adi Nifas_D01 and Adi Nifas_D02) are mainly used for Asmara town water supply, which limits irrigation use to seepage water downstream of these reservoirs. 15 of the remaining 43 reservoirs were designed for human and livestock consumption and are class two reservoirs, but some irrigation is practiced also (Table 3.14 and Appendix 4). The following discussion on agricultural water use, current irrigation and future irrigation potential largely excludes the reservoirs used for Asmara water supply (Map 3.1). It includes 3 cases where seepage water of town supply reservoirs is used for irrigation, but the area irrigated with this water accounts for only 12% of the total irrigated area (62 of 487 ha).

In Upper Anseba, 19 of the 49 reservoirs in the catchment are used for irrigation and fall into class one. The extent and intensity of irrigation differs considerable between them. Accordingly, irrigation can be categorized into good, medium and low grade depending on the experience of farmers and the availability of land and water. For example, Lamza and Ametsi can be taken as role models for irrigation in Zoba Maekel. Farmers in these two locations are not only good at producing but also at marketing, including delivery of produce directly to consumers.

Some reservoirs are shared between two neighboring villages because dam and reservoir were constructed in areas jointly owned by the two villages. Examples include the reservoirs of Laguen and Adi Hamushte; Adi Ghebru and Adi Teklay; and Hayelo and Gheshnasm; reservoirs are shared and water and land are used jointly and in harmony.

Figure 3.15 Irrigation from seepage water downstream of Adisheka town water supply dam

Figure 3.16 Irrigation at Laguen and Adi Hamushte: Villages sharing the same dam water

In villages which do not irrigate despite the existence of a dam, the main constraint is shortage of water, which these cases is used for livestock and domestic purposes only. However, in some places, lack of awareness and experience as well as mismanagement of resources were also identified as reasons for not practicing irrigation. The case of Tseazega and Zagr can be mentioned as examples. In Tseazega, there are two reservoirs which were used for irrigation until 1996. But currently there is no irrigation practiced from the second dam because the irrigeable area was planted with eucalyptus. In Zagr, there is a severe water shortage and the water is used only for livestock watering for a limited period each year. The downstream area has been planted with eucalyptus some 80 years back by a few farmers and all the seepage water from the dam is consumed by these trees.

Figure 3.17 Eucalyptus trees planted downstream of the reservoirs at Tseazega (left) and Zagr (right) consume the seepage water which could be used for crop production

Current and Potential Irrigable Areas

In almost all villages surveyed by this study average land holding per household was less than 0.5 hectare. The areas allocated for irrigation are shared among all villagers, and are fragmented into small plots based on land fertility and topography. The total currently (2007) irrigated area in Zoba Maekel is 487 ha, of which 322 ha are located within Upper Anseba Catchment (Table 3.15, details on Tables 3.13 and 3.14). The total number of beneficiaries from these reservoirs was estimated to be 11,720 households (Zoba Maekel) which is equivalent to the number of rural households of the villages with a reservoir, as every household of a given community has a right to have a piece of irrigable land.

Table 3.13 Irrigation from Class One Active Reservoirs in Upper Anseba and Zoba Maekel

S.No	Reservoir	Year of construction	Design capacity (M^3)	Current IRrigation (ha) (2007)	Potential irrigable (ha)*
1	Hazega	1982	40,000	7	4
2	Tseazega	1988	230,000	33.5	23
3	Shinjibluk	2007	350,000	10	35
4	Adi Kontsi-D01	1970	250,000	2	25
5	Ametsi	1988	180,000	30	18
6	Adi Asfeda	1988	200,000	32	20
7	Adi Habteslus	1941	80,000	4	8
8	Adisheka	Before 1930	5,100,000	12	20
9	Adikolom	1989	270,000	5	27
10	Embaderho-D01	1992	330,000	24	33
11	Guritat-D01	2006	300,000	6	30
12	Hayelo	1995	1,000,000	40	100
13	Mekerka	2003	270,000	16	27
14	Mesfinto	1995	60,000	9	6
15	Shmangus laelai	1985	400,000	15	40
16	Shmangus Tahtai	1992	230,000	15	23
17	Teareshi	1989	280,000	11	28
18	Adi Nefas_D01	Before 1930	600,000	30	-
19	Adi Nefas_D02	1941	200,000	20	-
20	Daero Paulos	1987	60,000	2	6
21	AdiGhebru-AdiTeklay	1985	160,000	6	16
22	Tselot_D03	1989	250,000	2	-
23	Tselot_D02	2005	300,000	3	30
24	Adi-Ahderom	2007	250,000	12	25
25	Laguen-AdiHamushte	1995	1,300,000	29	130
26	Himbrti Shaka	1985	400,000	11	40
27	Himbrti Gomini	1989	450,000	15	45
28	Laguen	1987	200,000	15	20
29	Adi Gombolo	1982	150,000	7	15
30	Adi Hawesha	1988	150,000	5	15
31	Lamza	1986	500,000	18	50
	Total (Maekel)			447	859
	Thereof (Anseba)			322	467

- Reservoirs with Serial No 1-19 are within the Upper Anseba Catchment, while the rest are outside of the Catchment but located within Zoba Maekel.
- AdiSheka, AdiNefas_D01 and AdiNefas_D02 are town supply reservoirs where irrigation is practiced from seepage water.
- * The potential irrigable area is based on the design capacity of the reservoirs, i.e. the figure in the Table does not include siltation.

In addition to the 487 ha of irrigation which is practiced from class one reservoirs, about 40 ha are irrigated by water from some of the class two reservoirs (Table 3.14).

Table 3.14 Irrigation from Class Two Reservoirs in Upper Anseba and Zoba Maekel

Logo	Reservoir	Year of const.	Design Capacity (m^3)	Current irrigation (ha) (2007)	Potential irrigable (ha)*
1	Adi Merawi	1992	110,000	3	11
2	TsaedaChristian	1944	80,000	4	8
3	Adi Musa	1992	250,000	2.5	25
4	Adi Kontsi_D01	1970	250,000	2	25
5	Adi Yacob	1993	80,000	3	8
6	Adi Musa	1992	250,000	2.5	25
7	Tsaeda Emba	1980	55,000	2.5	6
8	Adi Bidel	2007	90,000	-	9
9	Guritat	1997	180,000	3	18
10	Zagr	1984	150,000	2	15
11	Adi Arada	2007	200,000	3	20
12	Himbrti	1986	150,000	2	15
13	Selaadaero	1981	80,000	6	8
14	Adi Keshi	1988	250,000	2	25
15	Adi Teklay	1988	53,000	3	5
	Total (Maekel)			40.5	223
	Thereof (Anseba)			24.5	150

- Reservoirs with Serial No 1-19 are situated within the Upper Anseba Catchment while the others are outside of the catchment, but located within Zoba Maekel.
- * The potential irrigable area is based on the design capacity of the reservoirs, i.e. the figure in the Table does not include siltation.

The main constraints for the expansion of irrigation are availability of water and inefficient design of water controlling and distribution systems. Based on the design capacity of the reservoirs, the total potential irrigable area in Zoba Maekel was estimated to be 1082 ha (Tables 3.13 plus 3.14). Taking into account siltation losses, this figure has to be reduced accordingly (by 23%) which brings the real potential irrigable area down to 833 ha. Only 58 % of this real potential is currently (2007) used within the whole Zoba Maekel. In other words, an additional 346 ha could be irrigated at present within the Zoba, of which 129 ha in Upper Anseba, using the currently available reserved water. These calculations take water as the only limiting resource, as it is assumed that additional land could be prepared or reclaimed by indigenous soil conservation structures such as bench terraces and other appropriate land management practices to become suitable for irrigation.

For easier reference, the figures presented in Table 3.13 and 3.14 are summarized in Table 3.15 below. It presents an overall picture on current irrigation and irrigation potentials including all reservoirs (class one plus class two) where irrigation is currently practiced within the study area.

Table 3.15 Current and potential irrigable area in Upper Anseba and Zoba Maekel (2007)

	Upper Anseba	Zoba Maekel
Currently irrigated area (ha)	346	487
Potential irrigable area (ha) calculated on the basis of design capacity	617	1082
Potential real irrigable area (ha) estimated from actual capacities (design capacity less volume lost by siltation)	475	833

Agricultural Inputs and Production

Crops Grown

A variety of horticultural crops are grown in the irrigated areas. The crop grown most widely and considered to be most valuable as a cash crop is potato. Tomato, cabbage, carrot and salad are also widespread. Maize, garlic, spinach and alfalfa are grown to a lesser extent. It is not common to grow onions in the highlands but Hayelo, Guritat, Adikolom and Shmangus Laelay have been trying to introduce the crop in recent years with the result that it is now common in these places, especially in Hayelo Geshnashm.

Agricultural Inputs

The Ministry of Agriculture branch offices at subzoba level supply farm inputs such as fertilizers, seeds, pesticides and other materials to farmers at fair prices though often not on time and in required quantity. Farmers therefore complain that supplies are not sustainable/ reliable and try to get the inputs from private sellers, who sell at a very high price. Where pumps are used, farmers face price and availability problems relating to fuel.

Market Accessibility, Transport and Storage

Farmers do not have proper facilities to store their produce. Thus they are forced to sell at low prices during the main harvesting time, especially the perishables (tomatoes). Asmara, the main and most important market for agricultural products is located at the center of Zoba Maekel, i.e at the Southern fringe of Upper Anseba. It is easily accessible for the majority of farmers in the study area. Generally speaking the road network is appropriate. Transport is done on foot, by animals or vehicles. Many farmers also sell in nearby markets like Serejeka. The few farmers who are out of easy reach of the main road sell at farm gate to wholesalers who use their own transport. Overall, the study showed that most of the farmers sell over 90% of their products and leave the low quality products for household consumption.

Figure 3.18 Farmer in Lamza harvesting carrots, one of the major horticultural crops in the area

Irrigation System and Infrastructure

Furrow and basin irrigation are the most widespread irrigation practices. Furrow irrigation is mainly practiced in subzobas Serejeka and Berik, while basin and furrow irrigation are common in Subzoba Galanefhi.

Figure 3.19 Basin Irrigation at Himbrti, Galanefhi Subzoba (left), Furrow irrigation at Adi Asfeda, Berik Subzoba (right)

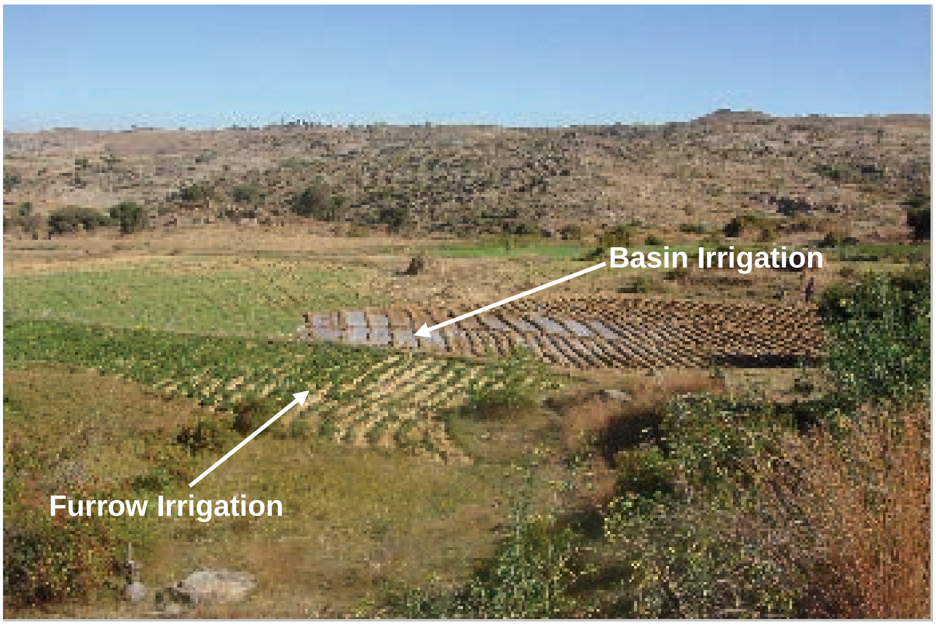


Figure 3.20 Basin and furrow irrigation combined, Subzoba Galanefhi

Water conveyance systems are mainly open furrow or open channel, sometimes combined with lined or piped channel. Water is lifted or delivered to the furrows by diesel or petrol pumps. In Himbrti Shaka, Himbrti Gomini, Laugen-AdiHamushte, Ametsi, Adi Asfeda, Merkerka, Embaderho, Adikolom, Hayelo-Geshnashm, and Tseazega, improved pipes are used. In Lamza, lined concrete channels are in use. In Geshnashm a pilot scheme has been installed using pressurized sprinkler irrigation which runs on electricity. Where irrigated plots are close to the water source, mainly on the upstream side of reservoirs, farmers use buckets to carry the water.

In general the irrigation system in Upper Anseba can be characterized as inefficient and labor-intensive. The use of closed piping for water distribution and the introduction of sprinkler and drip irrigation could help improve overall efficiency.

Figure 3.21 Different water conveyance systems for irrigation in Zoba Anseba

Irrigation Schedules

Most villages grow two crops per year, and a few farmers grow three crops. Mixed cropping is practiced by few villages, but it helps use time and resources efficiently. Most farmers irrigate once per week unless the crops are at flowering stage. The amount of water used is not known and is not uniform even within one and the same field. Farmers tend to apply water until the fields are oversaturated. They are limited by the availability of fuel for pumping, and by the availability of water. This shows that irrigation is still dominated by tradition and does not include efficient and sustainable use of water. Apparently, there is no solid basis for determining irrigation dates and amounts to be applied optimally. In short, the irrigation sector suffers from a lack of irrigation scheduling based on sound information, and there is an urgent need for its implementation given the increasing competition for water in future. In order to promote irrigation scheduling, water budgets of four main crops (potato, tomato, carrot and cabbage) are presented in the following sections as a model or pilot. These budgets show how much water must be applied on a weekly basis to the respective crop.

Soil-Water Budget

Irrigation scheduling is based on soil-water budgets; these support users in their decision about when to irrigate and how much water to apply. The method consists of assessing the incoming and outgoing water flux into the crop root zone over a given time period (Figure 3.22).

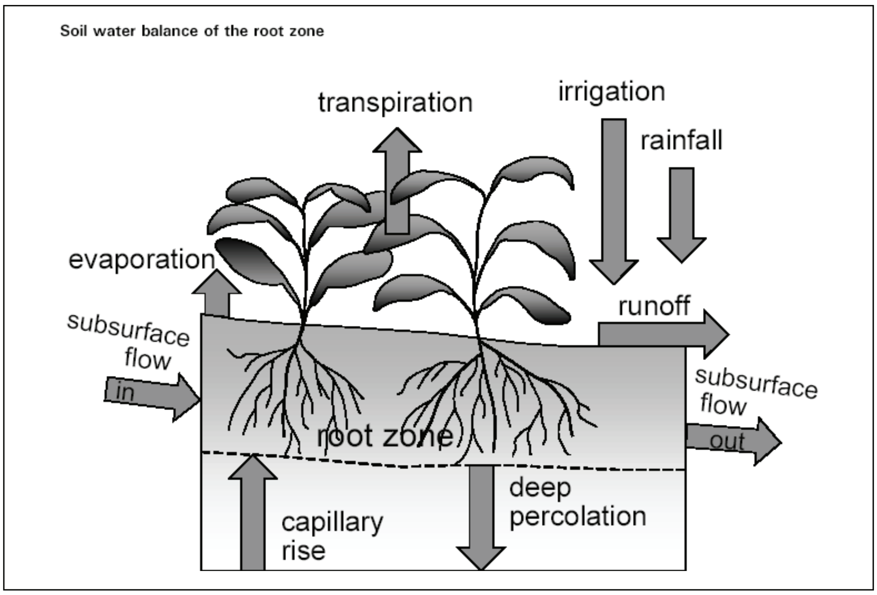


Figure 3.22 Soil Water Balance of the Root Zone

If the initial available soil water can be determined, the required amount of water over the irrigation period can be estimated by the following equation:

$$+SW = I + P - RO - DP - ET + CR \pm SF$$

In this equation, irrigation (I) and rainfall (P) are defined as water being added to the root zone. Some of I and P might be lost by surface runoff (RO) and by deep percolation (DP), which will eventually recharge the groundwater table. Water might also be transported upward by capillary rise (CR) from a shallow water table towards the root zone or even be transferred horizontally by subsurface flow into the root zone (SFin) or out of it (SFout). In many situations, however, except on terrain with large slopes, SFin and SFout are minor and can be ignored. Soil evaporation and crop transpiration deplete water from the root zone. If all fluxes other than evapotranspiration (ET) can be assessed, the evapotranspiration can also be estimated from meteorological data using the standardized Penman-Monteith equation. Finally the required soil water content (SW), in other words the crop water requirement, can be calculated. Some fluxes such as subsurface flow, deep percolation and capillary rise from a water table are difficult to assess and short time periods cannot be considered.

Potential Evapotranspiration (ETo)

In order to determine potential evapotranspiration (ETo) in more detail, data from Afdeyu and Asmara meteorological records were used (Table 3.16 and Table 3.17). Owing to the difficulty of obtaining accurate field measurements, evapotranspiration (ET) is commonly computed from meteorological data. A large number of empirical or semi-empirical equations have been developed for assessing crop or reference crop evapotranspiration from meteorological data. The FAO Penman-Monteith method is generally recommended as the standard for the definition and computation of the reference evapotranspiration (ETr). The data used are mean monthly maximum and minimum temperature (°C), relative humidity (%), sunshine hours, wind speed (km/d) and solar radiation ($MJ/M^2/d$).

Some of the Afdeyu data (relative humidity, wind speed, global solar radiation) have only been collected for one year when this study was done. Thus the ETo values based on this station are less reliable than the ETo value calculated from the Asmara meteorological data, which cover two decades.

The ETo values of Afdeyu vary between 2.3 mm/day in December and 5.5 mm/day in March, April and June. These values are lower than those for Asmara; here, the lowest ETo value was found in August (3.8 mm/day) and the highest in May (6.6 mm/day). Note that Afdeyu is at a higher altitude than Asmara.

Table 3.16 Monthly ETo values computed from meteorological data of Afdeyu (2007) using CROPWAT

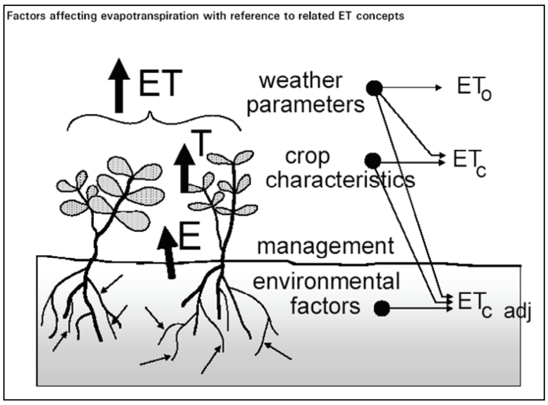
Month	Max. Tem (°C)	Min. Tem (°C)	Humid. (%)	Wind-speed (Km/d)	Sun-Shine (Hours/ day)	Solar radiation ($MJ/M^2/d$)	ETo (mm/d)
January	23.5	7.2	53	185.4	9.8	20.1	4.0
February	25.3	9.4	46	176.5	9.6	21.6	4.6
March	25.9	10.4	44	233.3	9.4	23.1	5.5
April	26.0	12.2	52	245.4	9.1	23.5	5.5
May	26.0	9.4	47	271.3	9.5	24.1	5.9
June	25.5	13.4	49	250.6	8.5	22.3	5.5
July	22.2	12.9	78	184.9	5.7	18.1	3.6
August	21.6	12.8	81	190.1	6.0	18.6	3.5
September	23.4	11.4	60	198.7	8.4	21.8	4.5
October	21.7	10.7	59	176.3	9.2	21.5	4.1
November	22.4	9.2	63	250.6	9.6	20.2	4.0
December	22.9	8	63	172.8	9.6	19.2	3.5
Average	23.9	10.8	57.9	211.3	8.7	21.2	4.5

Table 3.17 Monthly ETo values computed from meteorological data of Asmara (1998-2007) using CROP-WAT

Month	Max.Tem (°C)	Min.Tem (°C)	Humid. (%)	Wind-speed (Km/d)	Sun-Shine (Hours/ day)	Solar radiation ($MJ/M^2/d$)	ETO (mm/d)
January	23.0	4.2	53.0	371.2	9.4	19.7	5.0
February	24.5	5.5	46.0	406.1	10.1	22.4	5.9
March	25.5	7.5	44.0	414.7	9.2	22.8	6.5
April	24.5	9.3	52.0	423.4	9.3	23.9	6.3
May	25.5	10.9	47.0	414.7	9.2	23.6	6.6
June	25.3	11.4	49.0	406.1	8.5	22.2	6.2
July	22.2	12.2	78.0	388.8	5.5	17.8	3.9
August	22.0	12.2	81.0	371.5	4.8	16.8	3.8
September	23.5	9.6	60.0	345.6	8.6	22.1	5.1
October	22.2	9.0	59.0	423.4	9.9	22.6	5.1
November	22.1	7.3	63.0	345.6	10.4	21.4	4.4
December	22.5	5.4	61.0	354.2	10.5	20.5	4.4
Average	23.6	8.7	57.8	388.8	8.8	21.3	5.3

Potential Crop Evapotranspiration (ETc)

ETc is the amount of water lost through evapotranspiration from a disease free and well-fertilized crop. This value differs according to the canopy cover, development stage, and aerodynamic resistance of crops. In this study ETc was calculated from the reference evapotranspiration (ETo) estimated above and a crop coefficient (Kc) as ETc = ETo x Kc as indicated in Figure 3.23.



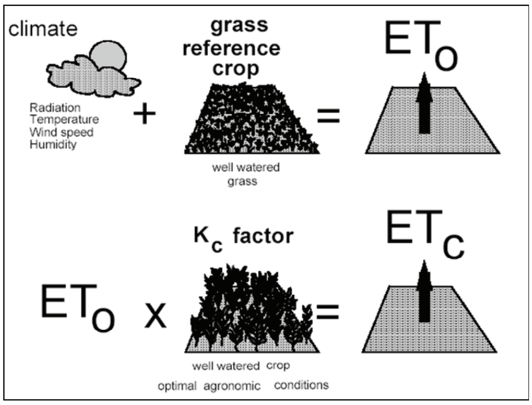


Figure 3.23 Parameters for estimating ETc (Source: FAO Report No. 56)

Crop Data

Since the ETc values differ with canopy cover and development stage of the crop it is necessary to look at the length of the crop development stages and their related crop coefficient (Kc) values in detail. Reference values were obtained from FAO Report No 56 and selected values are presented in Table 3.18 and 3.19. As the crop develops, the ground cover, crop height and the leaf area change. Due to differences in evapotranspiration during the various growth stages, the Kc for a given crop will vary over the growing period. The growing period can be divided into four distinct growth stages, which are initial, crop development, mid-season and late season.

Table 3.18 Length of crop development stages (days)

CROP	INI (L INV)	DEV (L. DEV)	MID (L. MID)	LATE (L.LATE)	TOTAL
Potato	25	30	30/45	30	115/130
Tomato	30	40	40	25	135
Carrot	20	30	50/30	20	100/120
Cabbage	40	60	50	15	165
Onion	30	55	55	40	180
Lettuce	30	40	25	10	100
Zuccini	20	30	25	15	90
Cauli flower	35	50	40	15	140
Spinach	20	30	40	10	100
Broccoli	35	45	40	15	135

Primary source: FAO Irrigation and Drainage Paper 24 (Doorenbos and Pruitt, 1977), Table 22
The four crop growth stages are:
INI (L INV) - Initial stage which runs from planting date to approximately 10% ground cover
DEV (L. DEV) - Crop development stage which runs from 10% ground cover to effective full cover
MID (L. MID) - Mid season stage which runs from effective full cover to the start of maturity
LATE (L.LATE)- Late season stage which runs from the start of maturity to harvest or full senescence

Table 3.19 Crop Coefficient (Kc) at different stages of crop development

CROP	Kc INITIAL	Kc MID	Kc END
Potato	0.5	1.15	0.74
Tomato	0.6	1.15	0.7-0.9
Carrot	0.7	1.05	0.95
Cabbage	0.7	1.05	0.95
Onion	0.7	1.05	0.75
Lettuce	0.7	1.00	0.95
Cauli flower	0.7	1.05	0.95
Spinach	0.7	1.00	0.95
Garlic	0.7	1.00	0.70
Broccoli	0.7	1.05	0.95

Crops require thus different amounts of water in the course of their development. The higher Kc values at middle stage as compared to Kc initial, or Kc establishment stage and Kc at late stage indicate that plants require more water during flowering and yield formation. Length of crop development stages and the Kc values for different crops are presented in Tables 3.18 and 3.19, and make it possible to calculate crop-specific ETc values. With these values, daily ETc estimates can be made which show the day-by-day soil water depletion relating to field capacity, and which can thus be used for irrigation scheduling. Therefore, it is necessary to first determine field capacity, and for this we have to turn to soils.

Soil Data

Soil is storehouse for plant nutrients, a reservoir for water, an environment for biological activity and an anchorage for plants. The root system of crops differs according to their genetic set up. Some crops have long roots that penetrate deep into the soil while others are shallow-rooted. The plant rooting system, soil characteristics, and water management determines the depth of the soil reservoir that holds water available to plants. In most plants, the concentration of moisture absorbing roots is greater in the upper part of the root zone, which is most favorable for aeration, biological activity, temperature and nutrient availability.

Field capacity (FC) is the quantity of water stored in a soil volume after drainage of gravitational water. Only a portion of the water can be removed from a volume of soil by a crop and this quantity is called "available water" (AW). The amount of available water within the crop root zone at any given time is often called "soil moisture reservoir". Unfortunately, only a fraction of the reservoir is readily available to the crop without water stress. The amount of the available water depends greatly on the soil texture and structure. A range of values for different types of soil is given in Appendix 6.

In addition, if one irrigates a specific crop, one has to select the Management Allowable Depletion (MAD) of the available soil moisture. MAD is defined as the percentage of the available soil water that can be depleted between irrigation events without causing serious plant stress. MAD should be determined according to type of crop, stage of growth and growing season. Recommended values for MAD depending on the depth of the root zone are as follows:

25 – 40%	for high value shallow-rooted crops
50%	for deep-rooted crops
60-65%	for low value deep-rooted crops

Root depths of the common crops in the study area are summarised in Appendix 6.

Recommended values for MAD depending on soil type are:
- Fine-textured soils (clayey) 40%
- Medium-textured (loamy) soils 50%
- Coarse-textured soils (sandy) 60%

For this study, the 50 % MAD value was used because most of the soils sampled and analyzed in the downstream irrigated fields of the 9 selected dams are medium-textured soils ranging from silt-loam to sandy-loam and loam. It is also known that generally, the total available moisture for loamy soils is 140mm/m, with a maximum infiltration rate of 10-20mm/day (Appendix 6).

Table 3.20 Some recommended MAD for crops at different growth stages growing in loamy soil

CROP	Crop growing stages			
	Establishment	Vegetative	Flowering yield formation	Maturity Ripening
Potato	35	35	35	50
Onion	40	30	30	30
Lettuce	40	50	40	20
Spinach	25	25	25	25
Garlic	30	30	30	30
Vegetables 30-60 cm root depth	35	30	30	35
Vegetables 90-120 cm root depth	35	40	40	40

SOURCE: Irrigation guide, USDA National Engineering Hand Book
MAD: Management Allowable Depletion, see text

Rainfall data and crop water requirement

In a next step, the amount of effective rainfall (Peff) must be determined. Rainfall data from the last 24 years was used to get the total precipitation of a whole year or a season. In a second step, effective rainfall for the growing season was obtained or computed using the USDA-Soil Conservation Service Crop Water Programme. Once potential evapotranspiration, Kc values, and effective rainfall are determined, the final step consists in calculating the crop water requirement of a specific crop, which is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field. As an illustration, a sample table is presented here (Table 3.21), showing the crop water requirement of potato in the Upper Anseba Catchment. Similar tables for three other common crops (tomatoes, carrots, and cabbages) can be found in Appendix 6.

Table 3.21 Crop water requirement table for potato in Zoba Maekel

Crop: Potato Time step: (days) 7 Irrigation Efficiency (%): 50

Date	ETO (mm/ Period)	Crop area (%)	Crop KC	CWR (ETc) (mm/ period)	Total rain (mm/ period)	Effective rainfall (mm/ period)	Irrigation Req. (mm/ period)	FWS (L/S/ha)
1\1	24.27	100.00	0.50	12.14	0.00	0.00	12.14	0.40
8\1	25.96	100.00	0.50	12.98	0.00	0.00	12.98	0.43
15\1	27.56	100.00	0.50	13.78	0.00	0.00	13.78	0.46
22\1	29.04	100.00	0.52	15.07	0.00	0.00	15.07	0.50
29\1	30.39	100.00	0.65	19.82	0.00	0.00	19.82	0.66
5\2	31.60	100.00	0.80	25.40	0.00	0.00	25.40	0.84
12\2	32.64	100.00	0.95	31.18	0.00	0.00	31.18	1.03
19\2	33.52	100.00	1.10	37.00	0.00	0.00	37.00	1.22
26\2	34.23	100.00	1.15	39.37	0.00	0.00	39.37	1.30
5/3	34.78	100.00	1.15	40.00	0.00	0.00	40.00	1.32
12/3	35.17	100.00	1.15	40.45	0.00	0.00	40.45	1.34
19/3	35.41	100.00	1.15	40.72	0.00	0.00	40.72	1.35
26/3	35.51	100.00	1.15	40.83	2.15	0.00	40.83	1.35
2/4	35.47	100.00	1.15	40.79	2.59	0.00	40.79	1.35
9/4	35.31	100.00	1.12	39.60	3.22	0.00	39.60	1.31
16/4	35.05	100.00	1.03	36.11	3.95	0.00	36.11	1.19
23/4	30.70	100.00	0.94	32.51	4.66	2.68	29.82	0.99
30/4	34.27	100.00	0.84	28.91	5.20	4.57	24.34	0.80
7/5	19.37	100.00	0.77	14.91	3.10	2.88	12.04	0.70
Total	604.26			561.56	24.86	10.12	551.44	[0.98]

CWR: Crop water requirement for a specific crop, calculated as ETo x Kc, also called consumptive use (cu)

IR: Irrigation requirement for a specific crop in (mm) for a given time set/period. IR can be calculated as: IR = CWR−P_{eff} i.e crop water requirement minus effective rainfall

FWS: Field water supply in l/s/ha assuming continuous supply

In Table 3.21, the crop area is taken to be 100 % which means that the whole field is planted with a single crop (in this case potato), which simplifies calculation. Irrigation efficiency for surface irrigation is taken as 50 % as water loss is high before it reaches the irrigated fields; as it can be seen from Figure 3.24, and as stated before in this report, the water conveyance system is one of the main factors behind the low efficiency of surface irrigation as it is currently practiced. The time step taken was 7 days because farmers in the study area usually irrigate their fields once a week. The total crop water requirement of a potato crop in Upper Anseba thus amounts to 562 mm, which is higher than the requirement of carrots (372 mm) or cabbage (337 mm), but lower than that of tomato (643 mm). If the potatoes are planted on the 1st of January, for example, it is possible that the crop gets some "Asmera" rain during its late stage, which reduces the amount of irrigation water that has to be applied by the value of the amount of effective rainfall. In Table 3.21, total rainfall (in the late stages of the crop) is about 25 mm, of which some 10 mm are effective; hence the irrigation requirement is reduced by this amount, to reach a total of 551 mm for the entire growing cycle of the potato crop. This amount is then converted into m^3 per ha per growing season, which is a more practicable figure. The result is shown in Table 3.22, which shows the irrigation water requirements that must be provided in the case of four key horticultural crops in Upper Anseba.

Table 3.22 Irrigation water supply (m^3/ha/growing season) for major crops in Upper Anseba

Crop	Tomato	Potato	Cabbage	Carrot
CWR (mm/period)	561	643	337	372
CWR (m^3/ha/growing period)	5610	6430	3370	3720

Figure 3.24 Inefficient water delivery or conveyance systems

The above calculations are examples for showing how irrigation scheduling can be done. It is expected that proper scheduling will improve the performance of any irrigation system currently in use. Specifically, it has the following benefits:

- Increased application efficiency by decreasing the amount of water applied
- Increased yields and thus increased profit
- Lower energy use
- Less nutrient leaching
- Less tail water runoff

Community Perceptions and Ambitions

Four villages were selected with the aim of obtaining an overview of the diversity of perceptions and ambitions found within the study area relating to reservoirs, water use, and irrigation. Villages with high and low irrigation performance were selected. Two villages actively involved in irrigation (Ametsi and Lamza) and two with low performance (Zagr and Tseazega) were thus chosen.

Livelihoods

Table 3.23 presents a summary of the livelihoods in the four villages. The results are based on group discussions that were held in each village; the groups were asked to list their sources of income and to prioritize these according to their importance.

Table 3.23 Source of income in order of importance for the community

Priority	Zagr	Ametsi	Tseazega	Lamza
1st	Rain-fed farming(Bahir)	Irrigation	Rain-fed farming	Irrigation
2nd	Herding	Rain-fed farming	Irrigation	Rain-fed farming
3rd	Trade	Herding	Herding	--
4th	Daily labor	Daily labor	Daily labor	--
5th	Public office	Trade	Trade	--
6th	Remittance	--	--	--

As the Table shows, Zagr and Tseazega mentioned rain-fed agriculture as the most important source of income. The second choice was rain-fed farming and herding, while daily labor and remittances were listed as third or fourth level sources. In Lamza, farmers have a strong focus on irrigation coupled with rain-fed agriculture, indicating a high dedication to irrigation. The people from Lamza think that the only way to succeed in farming is by developing irrigation.

Table 3.24 The contribution of the different income source in each village

Livelihood	Zagr	Ametsi	Tseazega	Lamza
Rain-fed farming	50%	25%	75%	13%
Irrigation	--	50%	13%	87%
Herding	25%	13%	4%	--
Daily laboring	13%	6%	4%	--
Trade	4%	6%	4%	--
Public office	4%	--	--	--
Remittance	4%	--	--	--

In Lamza and also in Ametsi, irrigation makes the largest contribution towards local livelihoods. About 50% (Ametsi) and as much as 87% (Lamza) of total income is obtained from irrigation (Table 3.24). The second pillar of livelihood in these two villages is rain-fed agriculture, but in Lamza this activity accounts for only 13% of income. In Ametsi, rain-fed agriculture is more important and here, supplementary activities like herding, daily labor and petty trade are also mentioned, but make only a minor contribution to total income. Zagr and Tseazega on the other hand mention rain-fed agriculture as the main source of income and hence of livelihoods. This activity contributes 50% in Zagr and as much as 75% in Tseazega. In Zagr, irrigation is not practiced; the village focuses on rain-fed farming in Bahri, a greenbelt zone and concession area on the Eastern Escarpment with two rain seasons, fertile land and a warm climate. Interestingly, most farmers in Zagr have access to extensive agricultural lands in that area. A common feature for both Tseazega and Zagr is the availability of a larger area for rain-fed agriculture as compared to other villages in Upper Anseba and Maekel in general. To sum it up, activities for securing a livelihood are more diversified, and provide a higher share of income than in the two villages practicing irrigation.

Prioritization of activities in terms of contribution to household incomes can be taken as an indicator for the commitment of the villages towards a certain type of activity. It can be assumed that the higher the share or amount of income from one activity, the higher the commitment is for this activity.

Community Ambitions, Personal Ambitions
In order to understand community ambitions or goals, the groups were asked to list resources and belongings that make a village or an individual person be considered as rich or as “having wealth”.

Starting with community ambitions, the group members were first asked to think of a list of resources they consider important. These were collected on a flip chart according to the order in which they were mentioned. The groups then prioritized these resources according to their importance. Table 3.25 presents the results.

Table 3.25 Resources by priority that make a village rich according to the village community

Priorities	Zagr	Ametsi	Tseazega	Lamza
1st	Clean water	Fertile land	Abundant water	Sufficient water
2nd	Potential for irrigation	Dam	Human power	Fertile land
3rd	Large irrigable area	Human power	Large farm land	Irrigation potential
4th	Land for animals	Terraced land	Road	
5th	Access road	Forest cover	Domestic animals	
6th	Forest cover	Large farm land	Forest cover	
7th	Mineral resources		Market place	
9th	Closures		Mineral resources	

The response in all four villages was similar. All agreed that natural or reserved water and fertile land are key resources for village wealth and well being. Availability of human power, terraced land, forest cover, closures, access road, market place and mineral resources were also mentioned. Differences between the villages exist, though. Zagr, for example, with less irrigation practice, put water for domestic purposes first and is thus the only village which does not give first priority to irrigation. Conversely, the village assigns significantly higher importance to livestock than the other villages. Tseazega and Lamza assign priority to water for irrigation. Ametsi chose fertile land as the first indicator of wealth. Land was also mentioned in second and third place in other villages, a reflection of the overall shortage of land. Again, Lamza was much more focused and did not mention resources other than those required for irrigation. This confirms the previous finding relating to their sources of livelihood. Two villages – one irrigating and the other not – mentioned human power as an important indicator of wealth. Forest cover, road access, and closures (!) were also mentioned. Forest cover got a higher mark in the two villages with low irrigation performance.

After considering the community level, people were asked to list belongings, assets, or qualities, which make a person to be identified as rich or wealthy by his or her community. The list was then again prioritized by the group. Table 3.26 gives a summary of the results.

Table 3.26 Belongings / Qualities that make a person rich in the eyes of the community

Priorities:	Zagr	Ametsi	Tseazega	Lamza
1st	Healthy and not lazy	Healthy	Healthy	Healthy
2nd	Educated person	Educated person	Children	Children
3rd	Owns large area	Positive attitude	Educated	Positive attitude
4th	Children	Have kids (children)	Positive attitude	Large farm
5th	Owns cattle	Owns a house to accommodate animals	Modern farming	Animals
6th	Source of remittance	Who owns many animals	Has wise wife	
7th			Owns many animals	

Undisputedly, health comes out as the prime attribute for wealth of a person. People suffer from a number of health problems in the area, which makes them aware of the importance of healthiness. As farming is their main activity, physical work is important, and a healthy body (and mind) is considered a prerequisite.

Second in making a person wealthy are children and education. Children can help in farming and are expected to help shoulder responsibilities and share the physical burden of the breadwinner or the mother from an early age. Moreover, children keep the name of a person or family for the next generation which is considered important in the life of rural communities. Education was mentioned in different contexts. The group in Ametsi defined an educated person as an individual who knows about the seasons and the timing related to crop husbandry. In Zagr, the group was referring to academic achievement, explaining that a person so educated will get a better job and will know better how to lead his life.

Other qualities were mentioned depending on personal resources and problems at home. Zagr for example mentioned the concession for the land at Bahri (which they may see in danger). In the other villages, a positive attitude including the willingness to cooperate was mentioned as an important trait of a wealthy person. Not least, the study team found it unique that the communities mentioned financial and material resources (animals, remittances) last; this could be indicative of relatively low economic disparities within the communities.

Community Priorities

Under this heading, community priorities relating to development in general were discussed with the groups. The procedure used was the same as for discussing community and personal ambitions.

All villages mentioned water development related activities, including irrigation, in first place, and often in second place again, except Tseazega, which put proper management of farmland first (Table 3.27). This village has a serious land tenure problem as farmland is not shared equally among villagers; therefore the existing tenure system was also mentioned as the main reason for the low irrigation performance. The priority items which follow after water development differ, but are related to the general wish for improving general social, educational, and health infrastructure. Again, Lamza is quite an exception with its focus on irrigation.

Table 3.27 Community needs by priority

Priorities:	Zagr	Ametsi	Tseazega	Lamza
1st	New dam	New dam	Proper management of farm lands	New wells
2nd	Bore a well	Water supply	Land for house construction	De-siltation of existing dam
3rd	Support on fertilizer	Electricity	Highschool education	New dam
4th	Kindergarten	Health facility	Upgrade health facility	Enlarge irrigation areas
5th	Secondary school	Road	De-siltation of existing dam	Electricity
6th	Connect to national electric grid	School	Road (asphalt) – transportation	
7th			Kindergarten	
8th			Market place	
9th			New dam	

Main Constraints

This section of the participatory appraisal focused on irrigation. The groups were asked to list the main constraints relating to irrigation in their community. The results are shown in Table 3.28.

Not surprisingly, the main constraints identified relate to the availability of water and land. Zagr presents an extreme case, as its unreliable water source, which dries up during the dry season makes irrigation impossible, forcing the community to limit water use to domestic purposes and animal watering. Even so, the reservoir water does not see them through the dry season. Water shortage is also a problem in the other villages but to a lesser extent. Secondly, shortage of land and land tenure were mentioned as constraints. Shortage of land frustrates people's desire to irrigate, as they consider the additional benefits derived from irrigating tiny plots as minimal. Villagers in this situation look for external support for levelling rugged land that could then be used for irrigation. The land tenure system currently in place plays a negative role, because farmers are discouraged to invest in their land which they know will be given to another person within the 7 year rotation cycle followd in the rural highlands. Their reluctance for investing increases as the time of redistribution approaches. The third common issue is the limited supply of key inputs – improved seed, fertilizer and pesticide. Basically, this problem seems to be temporary and easy to rectify, but the damage currently done is enormous. Most of these inputs used to be provided by the government but since 2006, the necessary amounts were not delivered in time. Prices from private dealers are exceptionally high and beyond the reach of the majority of farmers. In some cases the inputs were not available at all, even for those willing to pay. Lack of market, transportation problems, as well as shortage of irrigation equipment and tools were also mentioned as constraints. In sum, the constraints mentioned by the communities add up to a complex which substantially hinders irrigation development in Upper Anseba.

Table 3.28 Farmers' constraints relating to irrigation by priority

Priorities	Zagr	Ametsi	Tseazega	Lamza
1st	Water	Water	Land tenure problem	Shortage of water
2nd		Shortage of improved seed	Shortage of water	Shortage of land
3rd		Diesel shortage and expenses	Shortage of improved seed	Shortage of improved seed
4th		Shortage of fertilizer	Shortage of fertilizer	Shortage of fertilizer
5th		Shortage of agrochemicals	Shortage of agrochemicals	Shortage of agrochemicals
6th		Transportation problems	Lack of transportation	Shortage of irrigation tools
7th		Lack of market place (poor trade)	Market place (poor trade)	

Livestock Watering

Water needs other than for irrigation must also be considered in water allocation and management. The following paragraphs deal with the needs of the livestock sector.

Livestock Population

The general census from the Ministry of Agriculture Zoba Maekel branch office (2008) shows that the total livestock population in the Zoba is nearly 152,000 heads (Table 3.29). As the Subzobas of Serejeka, Berik and the four Subzobas that constitute Asmara are located in Upper Anseba, the livestock population in the study areas is about 100,000 animals.

Table 3.29 Livestock population of Zoba Maekel in 2008

SubZoba	Cattle	Sheep	Goat	Donkey	Horse	Mule	Camel	Total
Asmara	6,779	4,588	627	–	1,632	–	–	
Serejeka	15,624	21,027	5,050	8,722	10	63	7	
Berik	14,315	17,058	3,839	–	3,915	–	–	
Galanefhi	10,525	20,836	11,988	4,732	27	15	372	
Total	47,243	63,509	21,504	13,454	5,584	78	379	151,751

Source: MoA Zoba Maekel

Livestock Water Requirement

For a detailed analysis of the livestock sector, data on kind and number of animals of the nine selected reservoirs and or villages was taken based on the information collected from key informants (Chapter 4). In addition to this, farmers were asked to estimate the average water requirement per livestock head. Table 3.30 shows that the values given by farmers are lower than those indicated by MoLWE (1998). Farmers' lower values – 18 litres per day for cattle, 2.5 litres per day for smallstock and 10 litres per day for donkey, mule and horses – could be attributed to the cooler climate of this high altitude area, the type of animal breeds kept, and fodder type and availability. The figures obtained from farmers were then used to estimate the drinking water demand for the total livestock, which gave a total of 464,000 m^3 for Zoba Maekel and of 340,000 m^3 for the Upper Anseba Catchment.

In most villages, livestock has free access to the reservoirs as shown in Photo 3.25. Separate watering troughs for livestock are not common but can be found in Adi Merawi, Adi Bidel and Lamza. Wells downstream of the reservoirs for livestock watering are also rare, but a few villages (Himbrti, Lamza and Adi Nefas) use them in addition to watering stock directly at the reservoirs.

Table 3.30 Livestock water requirements according to farmer's information

Type of livestock	Water demand per head (L/day)*	Water demand per head (m^3/year)	Average water use per head (L/day) **	Water demand per head (m^3/ year)**	Total water demand (m^3/year)***
Cattle	27.0	9.9	18.0	6.7	316,500
Goats and sheep	5.0	1.8	2.5	0.9	76,500
Donkey, mules and horses	16.0	5.8	10.0	3.7	71,000
Total					464,000

Source: * Modified, from MoLWE (1998)
** Current survey
*** Based on number of livestock as presented in Table3.29, and actual livestock drinking water requirement as indicated by farmers

Figure 3.25 Reservoir water for livestock watering

3.2.2 Domestic Use

It is not easy to accurately estimate domestic water consumption especially in rural areas. Countrywide, domestic water consumption was estimated to be 17 and 22L/capita/day for 2002 and 2010 respectively (MoA, 2002). This per capita amount is below of what is considered necessary for maintaining good health. The low figures are the result of lack of adequate water supply infrastructure in most rural areas, including long walking distance to watering points, and, in some places, of insufficient supplies from these points.

The main sources of water for household consumption in Zoba Maekel and Upper Anseba are hand dug wells, often located downstream of reservoirs. Reservoirs are also used directly especially for washing clothes, but sometimes also for getting drinking water.

Figure 3.26 Villagers fetching water directly from reservoir using human labor or donkeys

Figure 3.27 Adi Asfeda ladies washing clothes using reservoir water

Rapid urbanization and industrialization are creating stress to Eritrea's water resources. The stress is particularly high in Upper Anseba as more than 50% of its population are urban dwellers. As has been mentioned earlier, a considerable amount of water is delivered to Asmara from the reservoirs at Toker, Adi Sheka, Mai Sirwa and Mai Nefhi. Urban areas are also main sources of pollution. Asmara city poses a threat to the discharge of Maibela River because it collects untreated water from industries, including tanneries, textile mills, and chemical industries, and domestic sewage is discharged untreated. The solid waste deposited around towns and urban settlements is another source of pollution for surface water and groundwater, especially when pollutants are leached during the rainy season.

3.2.3 Other Uses

While the main uses are irrigation, domestic use and animal watering, reservoirs can be, and are, used for fishing, recreation, mining operations and other purposes. Fish have been introduced in many reservoirs in the Upper Anseba Catchment. However, for the majority of the farmers fish is not part of their diet and no attempt has yet been made to familiarize farmers with this diet. Hence the fish die out whenever a reservoir is emptied in the dry season. Industrial use may pose a serious threat to other uses. For example, in Embaderho when the whole reservoir supply was used for mining in 2007 without permission from the community, all the fish died and the crops under irrigation completely failed.

As to recreation, MaiSirwa is the only reservoir currently used for recreation purposes. Its main aim is to provide water for Asmara. In the foreseeable future, more reservoirs in Upper Anseba and in the central highlands might be used for recreation due to increased urbanization and the vicinity of the capital.

Figure 3.28 Reserved water can be used for recreation and it is a habitat for a number of plant and animal species

3.3 Catchment Surface Water Management

3.3.1 The Local Level

The By-law

A by-law drafted by the Ministry of Agriculture Maakel branch is the only currently available regulatory document for water management in Upper Anseba. The by-law has five articles on a total of five pages and has been in force since mid of June 2004. The objective of the by-law is to ensure efficient use of dams and their downstream irrigable areas. The document settles the ownership of dams and reservoirs, establishes governmental and community institutions for the proper management of these infrastructures and for the promotion of their efficient and sustainable use. It also contains a coercion article to prompt farmers not to leave their irrigable plots idle. The study team took the opportunity to discuss the implications of the new by-law with the communities. The following paragraphs summarise the key findings of these discussions.

- The by-law puts the responsibility of dam management, maintenance and proper use into the hands of the users of the dam. This article is considered important by the government as it is held to contribute to ensuring sustainability of the infrastructure while taking away the burden of maintenance from the public sector. However, local communities see it differently; all communities visited asked for external maintenance and expect the government to do this job. Though it could be argued that maintenance is beyond the capacity of local communities, these could at least collect money to make a contribution towards maintenance. The most common maintenance problems are related to siltation and leaking; there is little the community can probably do to de-silt a dam or stop leakage, but it can do a lot to reduce siltation and to make use of leakage water.
- Article 3 of the by-law addresses the issue of unused or underused irrigable land. It says that a farmer who fails to irrigate the land assigned to him for a period of six months will have it confiscated after a three month grace period. The land is then allocated to another farmer or investor by the village administration. The aim of this article is obvious, especially considering the fact that the irrigation potential of the existing dams is not fully used. The effect was found to be twofold: First, farmers admitted that the article had created awareness about the existence of the by-law. They confirmed that generally, no farmer would want to leave his land undeveloped without reason; and that in case he or she is sick or otherwas not capable of using it, he or she could let it and get income from the rent. Second, when discussing the article with administrators, they admitted that it enabled them to exercise power in the event of farmers refusing to develop their land for whatever reason, to the detriment of the community at large. In short, without this by-law it would have been difficult for the agricultural offices to take action against people who might deliberately leave their land undeveloped.
- The by-law also elaborates on the institutional set up for water management, a crucial component especially relating to irrigation. The by-law foresees the establishment of committees at four levels. Starting from bottom to top, these are Water User Associations; Kebabi/village Committees; Desk Committees, and Zonal Committees. The Water User Association, which is formed at the village level, is responsible for maintaining reservoir infrastructure, for the distribution of water, for operating and

maintaining the conveyance system, and for implementing technical advice given by staff of the Ministry of Agriculture. For duties beyond its capacity, the Association may seek help from the Desk Committee the duty of which is to support farmers through training, provision of fertilizers, improved seed and other inputs, and technical support.

Existing Water Management

In Upper Anseba, inplementation of the institutional set up as proposed by the by-law is in its infancy at best. Of the eight villages surveyed by this study, four relied on Water Committees rather than on Water User Associations to look after the water infrastructure and regulate water distribution. The committees limited themselves to operating the conveyance system rather than assuming responsibility for all aspects of water supply including the reservoir, as intended by the by-law. The dams are mainly taken care of by the village development committees. In short, water management at the local level is still largely done as it was practiced before the new by-law came into force; water committees and development committees were both in place before 2004. Even so, these committees find it difficult to create the requisite commitment within their communities. Water committees, for example, commonly charge farmers for diesel but generally the fees collected cover only operation and maintenance costs of the pump and in some places like Geshnashim the fee covers fuel cost only. No provisions are thus made for reparation and replacement costs with very few exceptions. Such arrangements are of course not sustainable in the longer term.

Most of the villages see no point in having even a water committee. They call in a community assembly headed by the administrator, which then decides about water management issues, as it does on other issue such as land distribution, area closure, etc. A typical example is presented by the village of Zagr, where the assembly decided to use the reservoir water only for watering livestock, on the ground that water is neither sufficient nor safe for other uses. The assembly also decided that washing clothes near the reservoir must not be done in order to avoid contamination. Such regulations are practical and in most cases adhered to and hence should not be discarded as inappropriate just because they were taken by the "wrong" institutional body. The problem lies elsewhere: In the case of large infrastructure such as dams and reservoirs, technical expertise is required and this may be lacking in committees with a general profile. Lack of expertise may be coupled with lack of awareness or lack of concern altogether. All these factors undermine dam and reservoir management, and lastly irrigation development. The government has also played its role as it has stepped in to maintain and rehabilitate dams free of charge in the past, or to initiate soil conservation based on compensation; so farmers show little enthusiasm for doing the job themselves. In Adi Asefeda, for example, farmers irrigate land close to the water body which contributes to high siltation. In the same village, a small erosion hot spot identified by famers as the main source of silt in the reservoir has not been terraced by the community. Such incidences reveal a general tendency of reliance on the public sector, which is unrealistic in view of the personal and financial resources which are available to the government.

The fact that village communities irrigate without a water budget is mainly linked to the lack of technical expertise. It often creates severe financial problems for certain farmers who do not get enough water in the end. Moreover, pumping reservoirs completely dry such as it almost happened in Embaderho in 2007 destroys habitats and kills fish and birds. In Embaderho finally, staff of the Ministry of Agriculture strongly adviced the village administration to stop pumping water just before the dam run dry. Such a scenario could have been avoided by proper water management administered by a well organized and informed specific committee. Such a committee could also advice farmers in time on water budgets, irrigation schedules; and distribute water equitably and at costs which would include provisions for sustaining the water supply system in the long term.

4 Case Study Reservoirs

This second phase of the dam inventory - Chapter 4 - presents a detailed analysis of 9 selected reservoirs. Each of the reservoirs is analysed in its local context. This includes technical data on dam and reservoir; size and condition of catchment area with map, current irrigation practices and production. Recommendations are made for each reservoir concerning improvement of water management, including irrigation, covering an array of related aspects.

The selection of the reservoirs was based on criteria such as reservoir capacity, spatial distribution, current water use and management, and irrigation activities, as well as age of reservoir and accessibility. All 9 reservoirs are within Zoba Maekel, and 6 of them in are within Upper Anseba Catchment. The 9 reservoirs are Hayelo-Geshnashm, Zagr, Embaderho, Ametsi, AdiAsfeda, Tseazega, Lamza, Laugen-AdiHamushte and Himbrti Gomini. The survey was carried out in 2007.

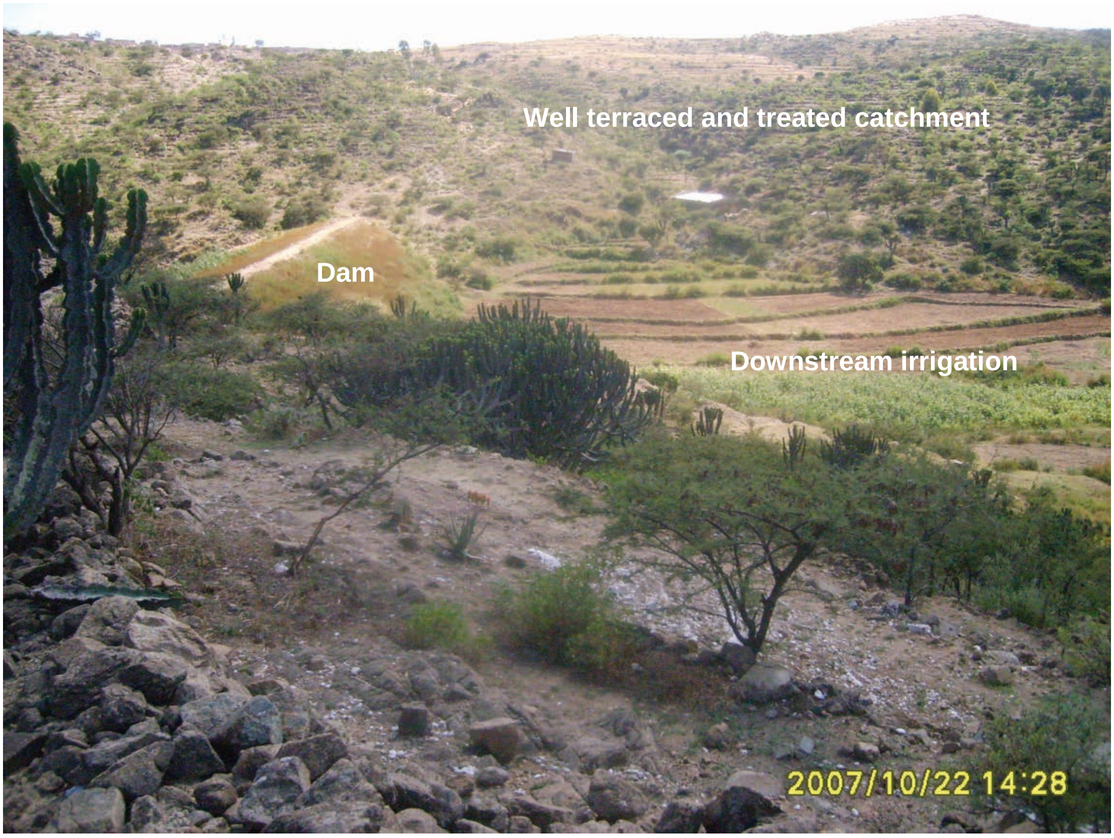


Figure 4.1 A well treated catchment, a reservoir and downstream irrigation at AdiGhebru-AdiTeklay

4.1 Hayelo Geshnashm Dam

Hayelo-Geshnashm is a rock fill dam built in 1998 between the villages of Hayelo and Geshnashm. It is owned by two villages and its water is used for irrigation and livestock watering by the two comunities. Seepage problems are evident and a second embankment was constructed downstream to use the water leaking leaking from the dam.

General Information

Location: 37 482621 E, 17 16791 N
Date of construction: 1998
Constructed by: MoA
Design Capacity: 1,000,000 m³
Actual capacity: 650,043 m³
Actual water volume at the time of survey: 69,551 m³
Dam crest length: 80 m
Dam height: 18 m
Type of dam: Rock fill

Condition of Catchment

The catchment area is almost 100% treated with physical and biological conservation methods. The upper part is enclosed and planted with eucalyptus and other, indigenous, species. The agricultural land at the lower part is also treated with soil and stone bunds covere with grass to stabilize the structures. Thus siltation rate has been reduced significantly in recent years.

Catchment area: 1035 ha (10 km²)
Slope: Undulating and slightly steep slope areas with small areas of moderate to steep slope
Catchment land cover types: see Table 4.1

Table 4.1 Catchment Land Cover Types, Hayelo-Geshnasm

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	6.4	0.62
Isolated (in natural vegetation or other) Rainfed Small Herbaceous Fields (field frequency 10-20% of respective polygon area)	357.9	34.57
Rainfed Small Herbaceous Fields	285.1	27.54
Rainfed Small Herbaceous Fields (mixed unit with natural vegetation or other) (field area approx. 60% of resp. polygon area)	110.2	10.64
Tree Plantation - Eucalyptus	17.4	1.68
Tree Plantation - Eucalyptus (mixed unit with natural vegetation or other) (field area approx. 60% respective polygon area)	244.5	23.62
Urban and Associated Areas	13.7	1.33
Total	1035.4	100.00

Irrigation

The irrigation intensity is mostly twice per year. The farmers start irrigation in February after the frost is over. The main crops grown are onion, tomato, potato, Cabbage, garlic, and pepper. The irrigation system is surface irrigation; basin and furrow; with PVC piped main channel and electric motor pump. In Geshnashim there is small plot of land with pressurized sprinkler irrigation as a model. The irrigation system is run by a committee elected by the two communities.

Number of beneficiaries: Hayelo - 240 households and Gheshnashm - 198 households
Surface area of currently irrigated fields: 40.5 ha
Potential irrigable area: 90 ha
Main horticultural crops: (Table 4.2)

Table 4.2 Horticultural crops in Hayelo-Geshnashm

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Onion	40	February	May	234	15
Tomato	40	February	May	139	11
Potato	15	15 May	July	278	8
Cabbage	5	July	Nov	334	3

Irrigation intensity: Twice/year
Irrigation interval: Once a week; twice a week at flowering
Irrigation system: Furrow and basin
Water conveyance system: Pipe system
Physical properties of the soil of the irrigable areas: Sandy loam
Frost occurrence: December - Mid February
Market: Serejeka
Percent of marketed produce: Over 90% (i.e. not consumed at household)
Production constraints: Lack of inputs; mainly seeds, seedlings, fertilizer, pesticides, sprayer (no supply or very expensive), post harvest storage problem, shortage of water (dam seepage)

Domestic Water use

Two drilled wells located downstream of the dam are used for domestic water supply. An estimated 40 liters/family/day for drinking, and 200liters/week for washing are consumed. Annually, domestic consumption amount to 3200m^3 and 4200m^3 for drinking and washing respectively.

Livestock Watering

Type and number of livestock and daily and yearly consumption are presented in Table 4.3.

Table 4.3 Type and number of livestock and their water consumption, Hayelo-Gheshnashm

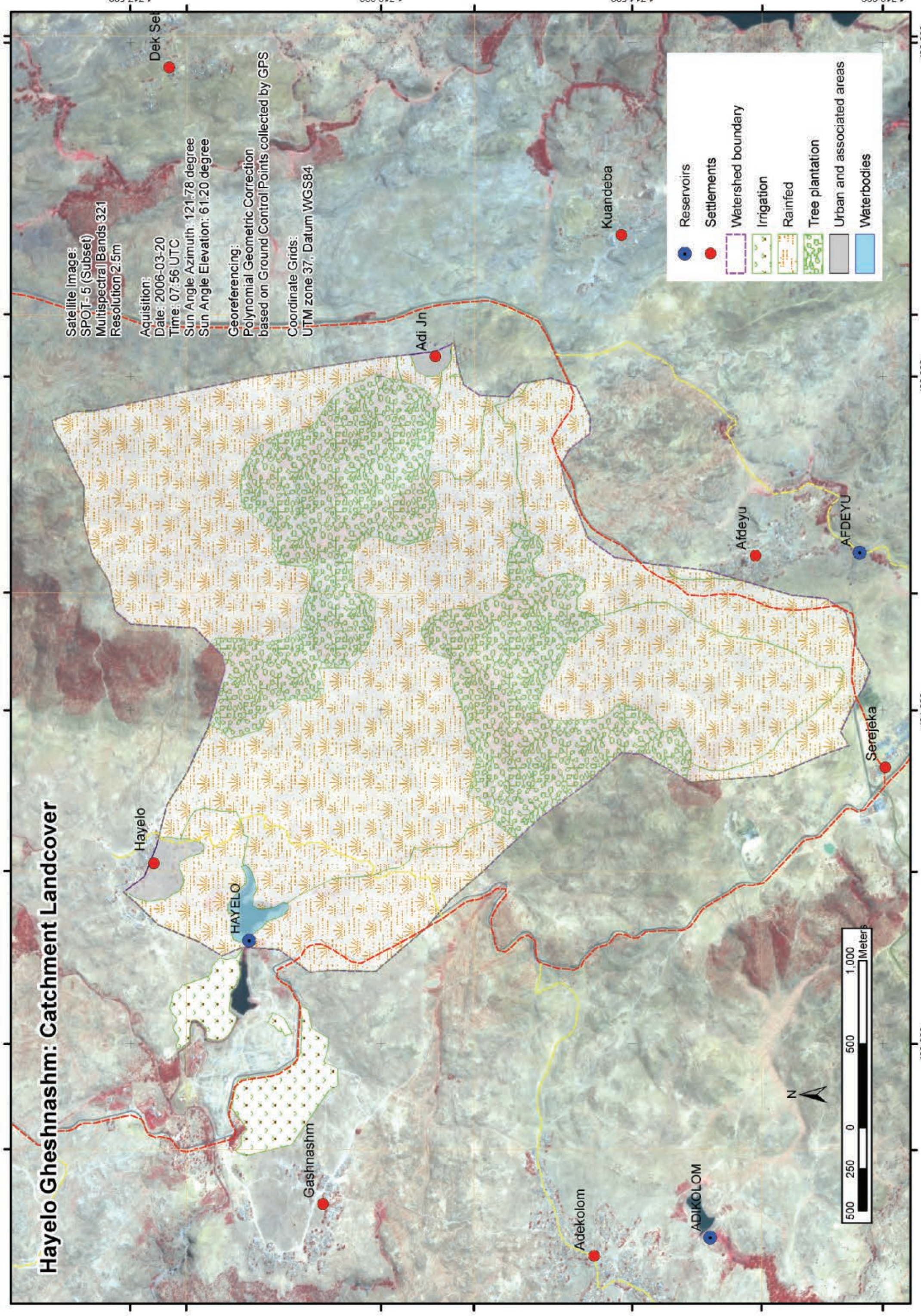
Type of Livestock	Daily water consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	500	3660
Sheep and Goats	3	100	110
Donkey	10	400	1464
Total			5234

Other uses

There are fish in the dam but it is not common in the area to eat fish.

Conclusions and Recommendations

- The dam needs rehabilitation to stop or minimize leakage.
- The reservoir should be fenced to keep the water relatively clean.
- Water user association needs to be strengthened to enhance proper management of the dam, the water and organize users.
- Irrigation should be in line with water availability (irrigation scheduling).
- Animals watering should not be directly from the dam; troughs have to be constructed on the downstream area.
- Crop selection could be re-thought so as to grow high yielding while less water demanding crops.
- Use frost tolerant crops during November to January to use the water available before it gets evaporated or is lost to leakage.



Map 4.1 Catchment land cover map of Hayelo-Gheshnashm dam

4.2 Zagr Dam

Zagr is located in Subzoba Serejeka, with its small reservoir constructed in 1984 by human labor under a food for work program. The reservoir is partially filled up with silt and needs to be upgraded.

General information

Location: 37 488333 E,
17 18554 N
Date of construction: 1984
Constructed by: MoA
Design capacity: 150,000 m^3

Actual capacity: 81,926 m^3
Actual water volume at the time of survey: 41,963 m^3
Dam crest length: 101 m
Dam height: 7.5 m
Type of dam: Earth fill

Figure 4.2 Zagr reservoir and downstream area

Condition of Catchment

The catchment area is mostly gently sloping agricultural land which is mostly treated; as the area is also used for grazing the soil and water conservation structures are not sustaining over a longer term.

Catchment area: 284 ha (2.84 km^2)
Slope: Mainly undulating with small patches of flat and slightly steep slope
Catchment land cover types: (see Table 4.4)

Table 4.4 Catchment Land Cover Types, Zagr

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	2.0	0.7
Open Shrubs	127.3	44.8
Rainfed Herbaceous Fields	83.1	29.2
Rainfed Small Herbaceous Fields	1.1	0.4
Rainfed Small Herbaceous Fields (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	38.3	13.5
Riverside Plantation – Eucalyptus	0.7	0.2
Tree Plantation – Eucalyptus	10.8	3.8
Urban and Associated Areas	20.9	7.4
Total	**284.3**	**100.0**

Irrigation

Number of beneficiaries: 814 households
Size of currently irrigated fields: 1 ha; no irrigation due to water shortage
Physical properties of the soil of the irrigable areas: Loamy soil
Production Constraints: Shortage of water

Domestic Water Use

Each household fetches on average
20 liter/day for domestic purposes, i.e.a total of 5,958 m^3 per year for the village.

Livestock Watering

Type and number of livestock and daily and yearly water consumption are presented in Table 4.5.

Figure 4.3 Eucalyptus trees planted on the downstream side of Zagr dam, 80 years ago

Table 4.5 Type and number of livestock and their water use, Zagr

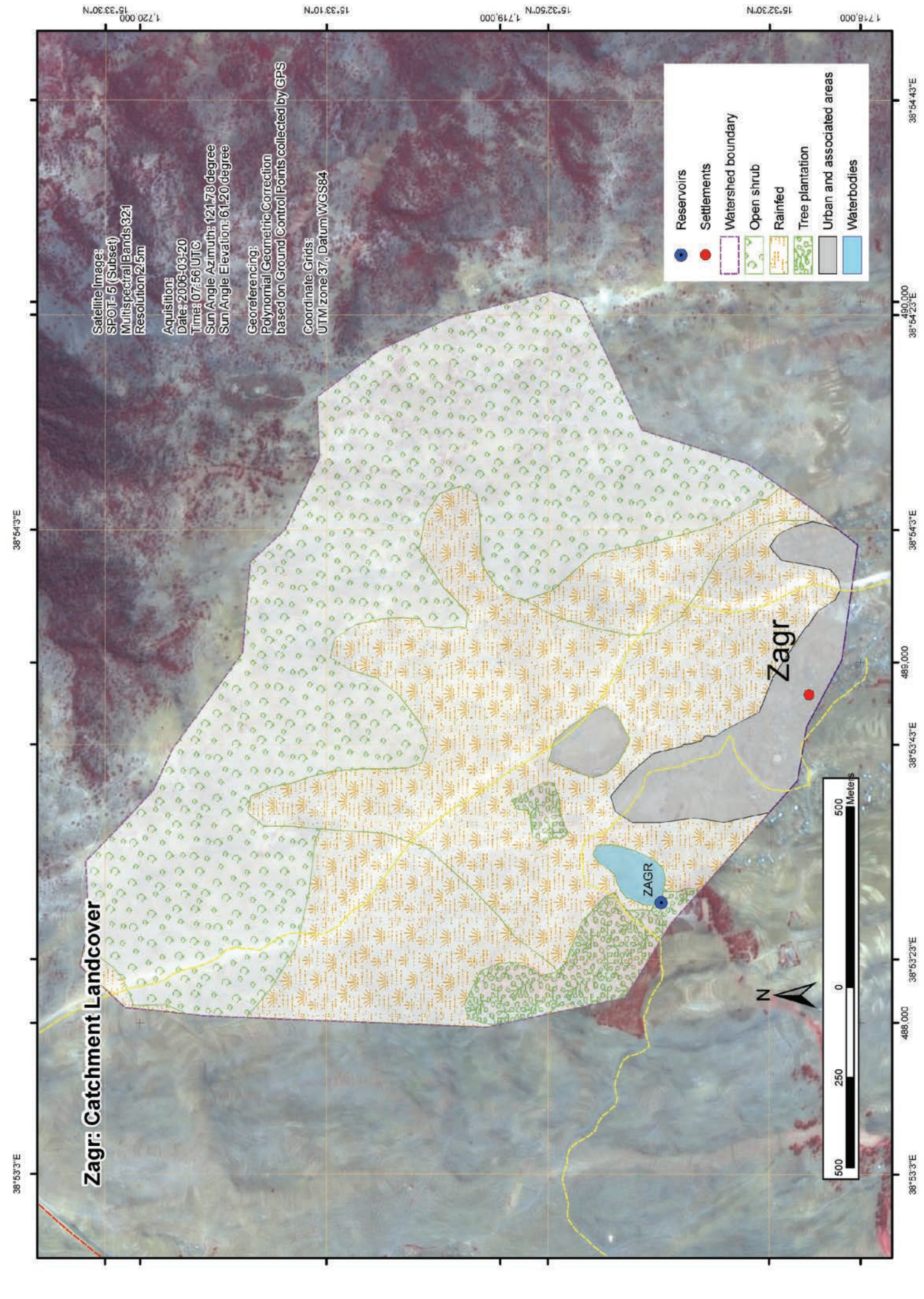
Type of Livestock	Daily water Consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	1000	7320
Sheep and Goats	2.5	5000	4575
Equines	10	1200	4392
Total			16,287

Other Uses

No other uses.

Conclusions and Recommendations

- The main reason given by the villagers for the absence of irrigation was shortage of water. However, many villages with less water and capacity than Zagir irrigate by digging shallow wells downstream of a reservoir. In Zagr, this area is planted with eucalyptus. Therefore, land use/ land tenure problems, lack of awareness, lack of a strong water user association, and poor agricultural extension can be mentioned as issues. The eucalyptus trees downstream of the dam should be cut and replanted on the upper catchment as "community forestry". Small scale irrigation can then be started to reduce food shortage.
- The dam should be rehabilitated and its crest raised.
- The reservoir should be fenced and animals should have troughs or watering points.
- The water user association should be strengthened and trained for better water management.



Map 4.2 Catchment land cover map of Zagr dam

4.3 Embaderho Dam

Embaderho is a large village on the border between Asmara town and Subzoba Serejeka;it is under the administration of Serejeka. A dam was first constructed during the Italian colonial era and failed in 1988. Few meters apart from that one, another dam was started by MoA and completed in 1992 by Lutheran World Federation (LWF).

General Information

Location: 37 488655 E,
17 05052 N
Date of construction: 1992
Constructed by: LWF
Design capacity: 330,000 m^3
Actual capacity: 314,833 m^3
Actual water volume at the time of survey: 166,306 m^3
Dam crest length: 180 m
Dam height: 8 m
Type of dam: Earth fill

Figure 4.4 Embaderho dam and environs

Condition of Catchment

The catchment area of the dam is dominated by settlement, (Embaderho village), agricultural land, and an area distributed for expansion of settlement (Tesa land). The sediment yield seems acceptable but of late, the Tesa land is the source of serious soil disturbance and during rains sediment yield might increase.

Catchment area: 240 ha (2.40 km^2)
Slope: Mainly undulating, with a small percentage of flat or slightly sloping land
Catchment land cover types: (See Table 4.6)

Table 4.6 Catchment Land Cover Types, Embaderho

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	10.0	4.1
Irrigated Herbaceous Fields	1.0	0.4
Isolated (in natural vegetation or other) Rainfed Small Herbaceous Fields (field frequency 10-20% polygon area)	21.5	8.9
Rainfed Small Herbaceous Fields	0.8	0.4
Rainfed Small Herbaceous Fields (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	38.3	15.9
Scattered (in natural vegetation or other) Rainfed Small Herbaceous Fields (field frequency 20-40% polygon area)	7.3	3.0
Tree Plantation - Eucalyptus	0.9	0.4
Urban and Associated Areas	160.6	66.8
Total	**240.4**	**100.0**

Irrigation

Number of beneficiaries: 1800 households (The irrigated fields are rented to 18 farmers for a total of 340,000 Nakfa per year).
Size of currently irrigated fields: 23.9 ha
Potential irrigable area: 35 ha
Main horticultural crops: (Table 4.7)

Table 4.7 Horticultural crops grown in Embaderho

Common Horticultural crops grown	Coverage in %	Planting	Harvesting	Yield Quintal/ha	Average price NKF/kg
Tomato	50	Feb	April	205	4
Potato	40	Feb	May	273	10
Carrot	4	Any time	After 3 months	320	5
Cabbage	2	Oct	Feb	330	4
Lettuce	1	Sep	November	386	3
Zuccini	2	May	July	164	4
Garlic	1	Sep	Feb	70	60

Irrigation intensity: Two to three times per year (200 - 300%)
Irrigation interval: Once a week, twice a week at flowering
Irrigation system: Furrow and basin
Water conveyance system: Open earth channel
Soil physical properties of irrigable areas: Loam to silty loam
Frost occurrence: November - February
Market: Asmara and Serejeka
Percent of marketed produce: Over 90%
Production Constraints: Lack of inputs mainly fertilizer, pesticides, and fuel for water pumps

Domestic Water Use

Two wells are used, one downstream of the dam; about 30% of the population uses it. If each household fetches 40 liters /day, total consumption would be 7880 m^3 per year.

Livestock Watering

Type and number of livestock and daily and yearly consumption of water in Embaderho are presented in Table 4.8.

Table 4.8 Type and number of livestock and their water consumption, Embaderho

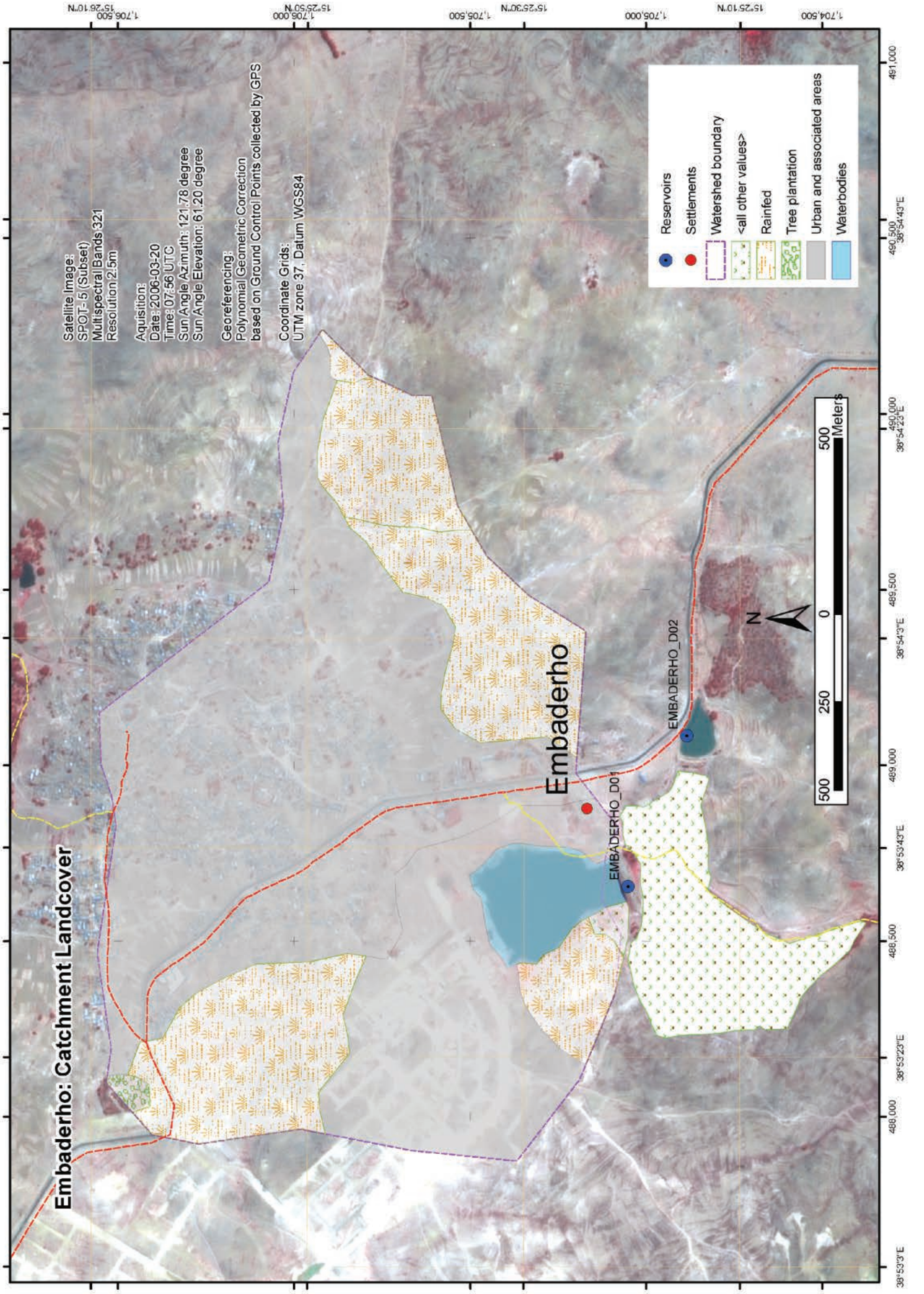
Type of Livestock	Daily water consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	1500	10,980
Sheep and Goats	2	10000	7,320
Equines	10	1000	3660
Total			**21,960**

Other uses

The reserved water is also used for house construction at a rate of approximately 6000 liters/day (farmers' estimation), which sums up to an annual demand of 2,200 m^3 per year.

Conclusions and Recommendations

- The dam is in good condition. The only way for increasing its capacity is by desilting. It cannot be enlarged as it is very close to the settlement.
- The irrigation intensity is encouraging. Even though there is a PVC main pipe of about 1.5 km, most of the main channel is earthen and conveyance loss very high. If the main channel can be completely changed to PVC piped conveyance, and the system be transformed to pressurized irrigation, the size of the irrigable area can still be increased.
- The water users association should be strengthened and trained, and it is suggested to use the scarce water resource mainly for irrigation.
- Special animal watering troughs should be constructed so as to control water born diseases; the reservoir should be fenced.



Map 4.3 Catchment land cover map of Embaderho dam

4.4 Ametsi Dam

Ametsi dam was built in 1988 by ECS and rehabilitated in 2004 by MoA, and its height increased by 2 m with a new spillway.

General Information

Location: 37 485355 E,
17 06555 N
Date of construction: 1988
Constructed by: Eritrean Catholic Secretariat (ECS)
Design Capacity: 180,000 m^3
Actual capacity: 118,720 m^3
Actual water volume at the time of survey: 99,304 m^3
Dam crest length: 116 m
Dam height: 10 m
Type of dam: Earth fill

Figure 4.5 Irrigated fields in the Gedena area downstream of Ametsi dam

Condition of Catchment

The catchment area is mostly agricultural land with old terraces which are grass-covered.

Catchment area: 166 ha (1.66 km^2)
Slope: Mainly undulating, and flat in some places
Catchment land cover types: (See Table 4.9)

Table 4.9 Catchment Land Cover Types, Ametsi

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	3.5	2.1
Irrigated Herbaceous Fields	1.2	0.7
Isolated (in natural vegetation or other) Rainfed Small Herbaceous Fields (field frequency 10-20% polygon area)	5.9	3.6
Rainfed Small Herbaceous Fields	74.7	45.1
Rainfed Small Herbaceous Fields (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	70.5	42.5
Urban and Associated Areas	9.9	6.0
Total	165.8	100.00

Irrigation

The village has a long experience in irrigation which started from hand-dug wells even before the dam was constructed. They use the dam in a relatively efficient way compared to other villages in Zoba Maekel. Currently they have 30ha under irrigation which is over and above the design capacity of the dam. This is possible because they use the dam as well as its downstream recharge by digging shallow hand dug wells for irrigation. The irrigation intensity is at least twice a year. The village is a well known vegetable producer in Asmara market. The community is better organized than others and has a water users association, though this one needs strengthening and training.

Number of beneficiaries: 330 households
Size of currently irrigated fields: 30.3 ha
Potential irrigable land: 12 ha
Main horticultural crops: (See Table 4.10)

Table 4.10 Horticultural crops grown in Ametsi

Common Horticultural crops	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Potato	60	Feb/May	May/August	120	10
Carrot	20	March	June	240	4
Tomato	10	March	July	200	8
Spinach	5	March	June	257	8
Cabbage	5	May	August	320	3

Irrigation intensity: Twice per year
Irrigation interval: Once a week, twice during hot months (May)
Irrigation system: Furrow and basin
Water conveyance system: Pipe system and open channel
Physical properties of the soil of the irrigable areas: Loam to sandy loam
Frost occurrence: December –January
Market: Asmara
Percent of marketed produce: Over 90%
Production constraints: Lack of inputs mainly seed and seedlings, tools, fertilizer, pesticides, and shortage of water.

Domestic Water use

The villagers use 200 liters/week/family for washing from the dam, and 60 liter/day/family for drinking water taken from a well downstream. The water thus deducted from the reservoir is 3160 m^3.

Livestock Watering

Type and number of livestock and its consumption is presented in Table 4.11.

Table 4.11 Type and number of livestock, Ametsi

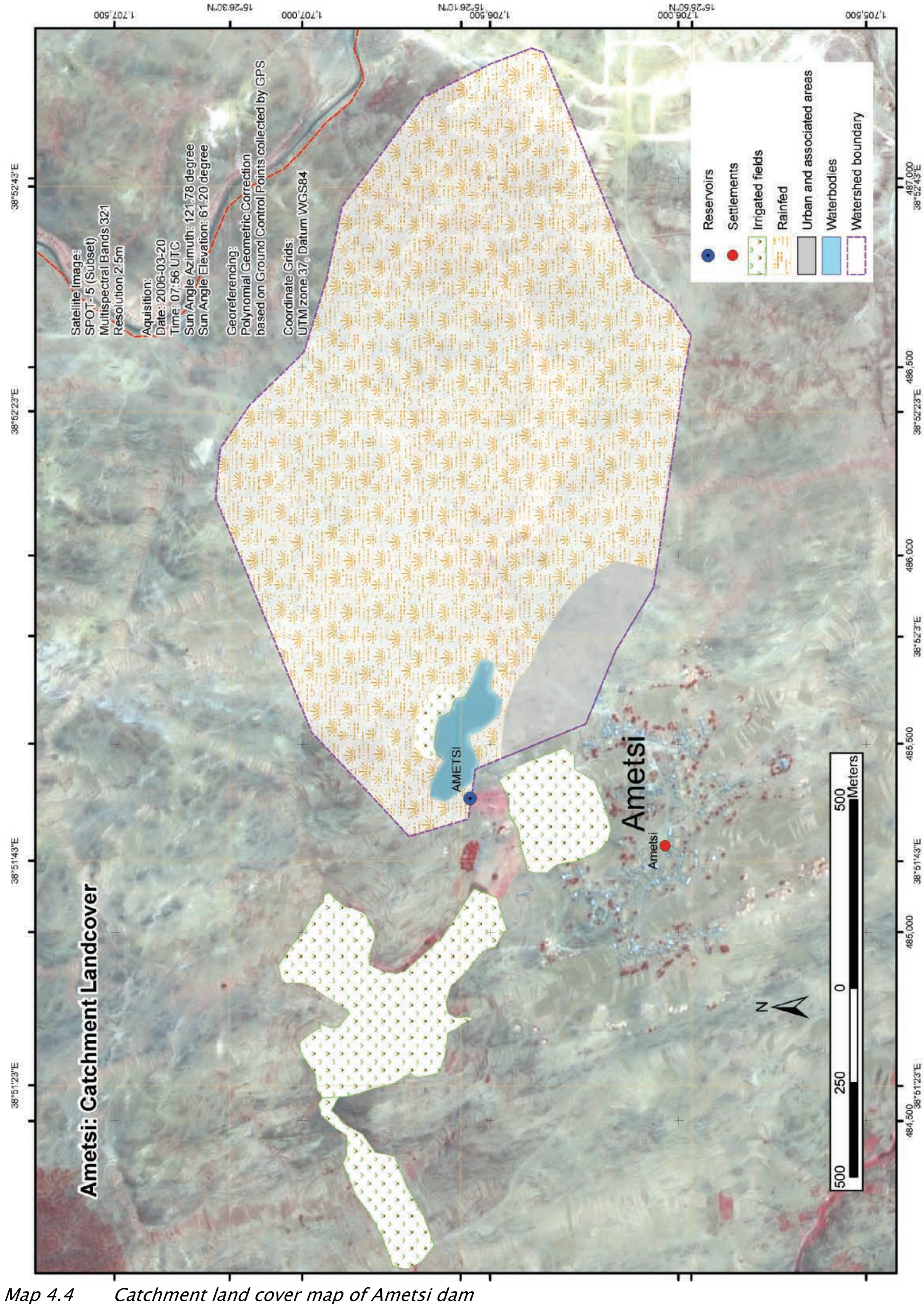
Type of Livestock	Daily water consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	10	300	1,098
Sheep and Goats	1	1800	659
Equines	5	300	549
Total			**2,306**

Other uses

No other use.

Conclusions and Recommendations

- The dam height can be increased, to increase reservoir capacity significantly.
- The village has a better water management than many, but a more efficient irrigation system could increase the irrigation area and reduce energy demand.
- In order to avoid water born diseases, cattle troughs should be made downstream of the dam, and the reservoir be fenced. For domestic use the village should have a lined and closed well the downstream of the dam.
- The catchment area should be kept properly treated so as to reduce siltation.
- The community user association should be strengthened.



Map 4.4 Catchment land cover map of Ametsi dam

4.5 Adi Asfeda Dam

Adi Asfeda is a village located in Subzoba Berik. Its dam was built in 1988 and rehabilitated and increased in height by 2 m in 2002. As a result its design capacity increased from 200,000 to 365,750 m^3 and its reservoir area from 6.4 ha to 10ha.

General Information

Location: 37 484950 E,
17 00905 N
Date of construction: 1984
Constructed by: MoA
Design capacity: 200,000 m^3
Actual capacity: 294,749 m^3
Actual water volume at the time of survey: 153,192 m^3
Dam crest length: 120 m
Dam height: 11 m
Type of dam: Earth fill

Figure 4.6 Adi Asfeda reservoir

Condition of Catchment

The catchment area of the dam is agricultural land also used as for grazing. It is treated with soil and water conservation structures but requires continuous maintenance. There is an erosion hot spot at Adi Shmagle ex-mining area near the main waterway. Cultivating around the reservoir aggravates erosion and contamination of reserved water.

Catchment area: 786 ha (7.86 km^2)
Slope: Mainly flat to undulating
Catchment land cover types: (See Table 4.12)

Table 4.12 Catchment Land Cover Types, Adi Asfeda

LC_TYPE	Area (ha)	% Catchment Cover
Artificial Waterbodies	13.4	1.7
Rainfed Small Herbaceous Fields	644.0	81.9
Riverside Forest	13.1	1.7
Urban and Associated Areas	115.7	14.7
Total	786.2	100.00

Irrigation

Currently 32.2 ha are irrigated which is above the design capacity. The farmers use additional water from 4 shallow wells dug downstream of the dam to make use of the recharged water for irrigation. In general the community has long experience in irrigation, going back to the time before the existence of the dam. They have better irrigation water management capacity than other villages. The water conveyance system is PVC piping for the main line, while the rest is open earth channel. The dam has got an outlet joined to about 1km of piped conveyance, which is not currently functional because some farmers failed to construct gates.

Number of beneficiaries: 180 households
Size of currently irrigated fields: 32.2 ha
Potential irrigable area: 30 ha
Main horticultural crops: (See Table 4.13)

Table 4.13 Horticultural crops grown in Adi Asfeda

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Potato	45	Sep-Feb	Dec-May	225	8
Cabbage	30	May-Oct	Aug-Feb	355	3
Carrot	10	May	Aug	300	4
Zuccini	5	Aug-Feb	Oct-April	375	6
Lettuce	5	May	August	150	5
Tomato	5	March	June	237	10

Irrigation intensity: Three times per year
Irrigation interval: Once a week
Irrigation system: Furrow and basin
Water conveyance system: Earth channel and pipe system
Physical properties of the soil of the irrigable areas: Loam to sandy loam
Frost occurrence: December -January
Market: Asmara
Percent of marketed produce: Over 90%
Production Constraints: Shortage of supplies in fertilizer, pesticide, and seed

Domestic Water Use

None from reservoir.

Livestock Watering

Type and number of livestock and their consumption are presented in Table 4.14.

Table 4.14 Type and number of livestock, Adi Asfeda

Type of Livestock	Daily water consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	15	150	824
Sheep and Goats	3	400	439
Equines	10	60	220
Total			1,483

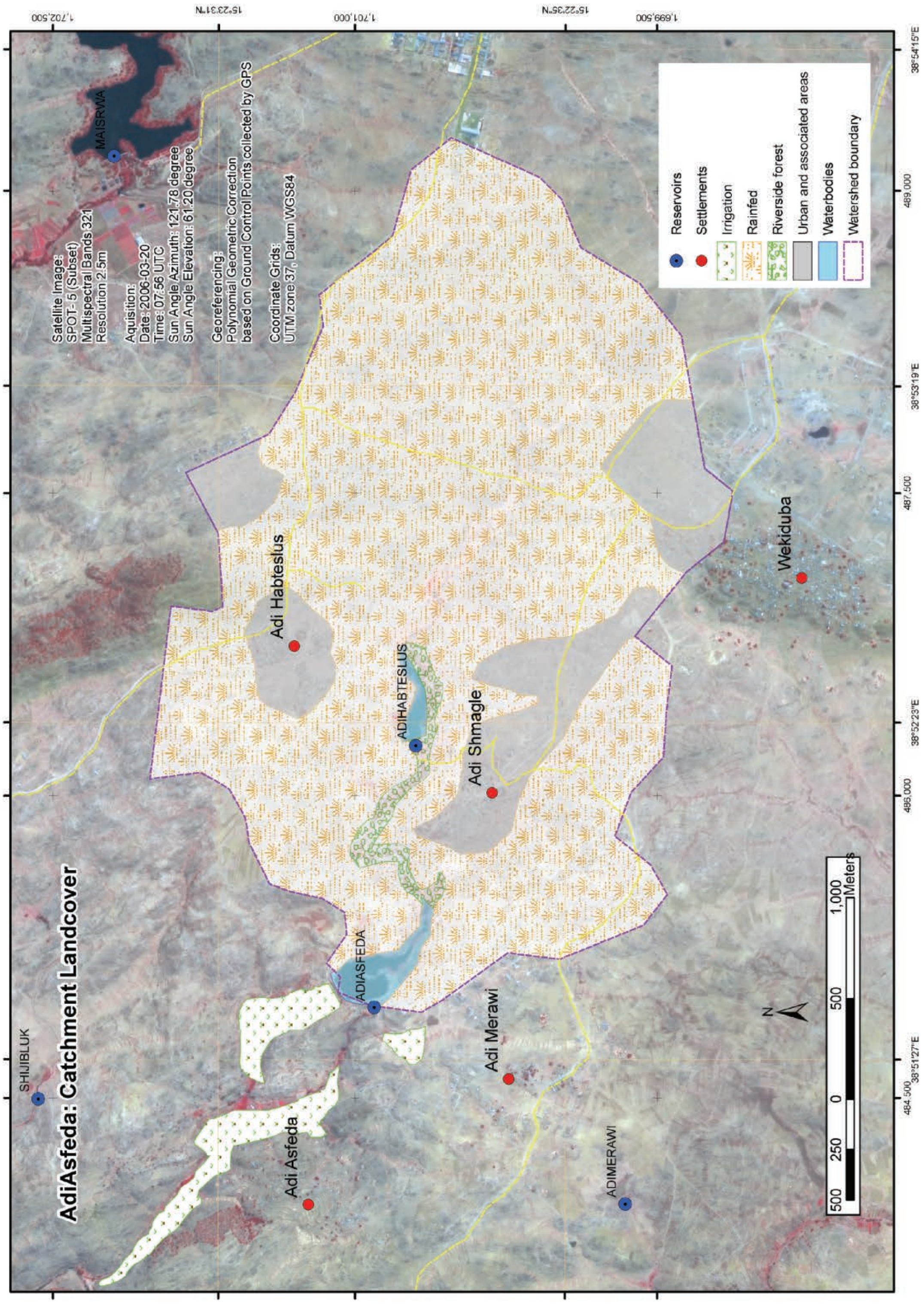
Other uses

No other use.

Conclusions and Recommendations

Farmers in AdiAsfeda have a long experience of irrigation. They also grow frost tolerant crops during the frost season. Water efficiency could be improved. Farmers irrigate up-stream close to the reservoir, which increases siltation and contamination. There are bushes on the dam body that can result in piping or can damage the dam. They have a very weak water user association which cannot enforce basic rules and regulations to use the dam water sustainably.

- There is an urgent need of strengthening the water user association to have proper management of the reservoir, dam body and the irrigation infrastructure down-stream.
- The community should be involved in reclaiming erosion spots and should stop plowing near the reservoir and water way.
- To control water pollution, the villagers should stop washing cloths and watering animals at the reservoir.
- Finally, it could be timely to improve the existing traditional irrigation system to semi-pressurized or pressurized irrigation to conserve water / irrigate more land.



Map 4.5 Catchment land cover map of Adi Asfeda dam

4.6 Tseazega Dam

Tseazega is a large village located in Subzoba Berik. Tseazega dam was constructed in 1988 by the Evangelical Church and was rehabilitated and increased in height by 2.3 m in 2000. As a result its capacity increased from 230,000 to 453,421 m^3 and the reservoir area increased from 7.1 to 15 ha.

General Information

Location: 37 4802260 E,
16 96267 N
Date of construction: 1988
Constructed by: Evangelical Church
Design capacity: 230,000 m^3

Actual capacity: 353,803 m^3
Actual water volume at the time of survey: 214,272 m^3
Dam crest length: 230 m
Dam height: 10.5 m
Type of dam: Earth fill

Figure 4.7 MoA staff members at the time of bathymetric survey in Tseazega

Condition of Catchment

The catchment area is mostly used for rain fed agriculture with a smaller grazing area and settlement. The area was once terraced but due to the recurrent land reallocations, fragmentation of land, and lack of maintenance the terraces are damaged. Natural forest is absent except a few remnants of Olea africana around the dam, some eucalyptus and Acacia saligna trees planted around the nursery and concession plots of Adikontsi.

Catchment area: 3761 ha in total, of which 1225 ha are diverted to MaiNefhi dam (Asmara town supply. Effective for Tseazega dam are therefore 2,536 ha (25.36 km^2). See Map 4.6. below.
Slope: Flat to undulating
Catchment land cover types: (See Table 4.15)

Table 4.15 Catchment Land Cover Types, Tseazega

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	38.9	1.7
Open shrub	209.7	9.1
Tree Plantation	6.5	0.3
Rainfed Small Herbaceous Fields	2019.2	87.6
Riverside Vegetation	8.4	0.4
Concession	21.7	0.9
Urban and Associated Areas	232.1	10.1
Total	2536.5	100.00

Irrigation

Tseazega dam has a good irrigation infrastructure. At least 2.5 km of the mainline is PVC piped with hydrants at about 100 m intervals. The system is equipped with two 25 horse-power motor pumps. However, the infrastructure is not in active use; the main reason for this could be lack of a strong water user association and the inappropriate land tenure system of the area, which makes that only few farmers can benefit from irrigation.

Number of beneficiaries: 1080 households
Area of currently irrigated fields: 33.5 ha
Potential irrigable area: 36 ha
Main horticultural crops: (See Table 4.16)

Table 4.16 Horticultural crops grown in Tseazega

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Tomato	40	Feb/August	May/Dec	250	8
Potato	40	Feb/May	May/ August	120	10
Cabbage	10	Sep	Dec	300	3
Zuccini	5	Feb	May	150	6
Carrot	5	July	Oct	150	4

Irrigation intensity: Twice per year
Irrigation interval: Once a week, twice during hot months (on May) and at flowering
Irrigation system: Furrow and basin
Water conveyance system: Earth channel
Physical properties of the soil of the irrigable areas: Loam to clay loam
Frost occurrence: December - February
Market: Asmara
Percent of marketed produce: Over 90%
Production constraints: Land tenure system, land reallocation (every 7 years), lack of farmer association, and lack of inputs such as fertilizer, pesticides, seed, and fuel.

Domestic Water Use

The villagers take 100 liters/day/household from a well downstream of the dam. This amounts to 39,530 m^3 per year.

Livestock Watering

Type and number of livestock and consumption rates are presented in Table 4.17.

Table 4.17 Type and number of livestock, Tseazega

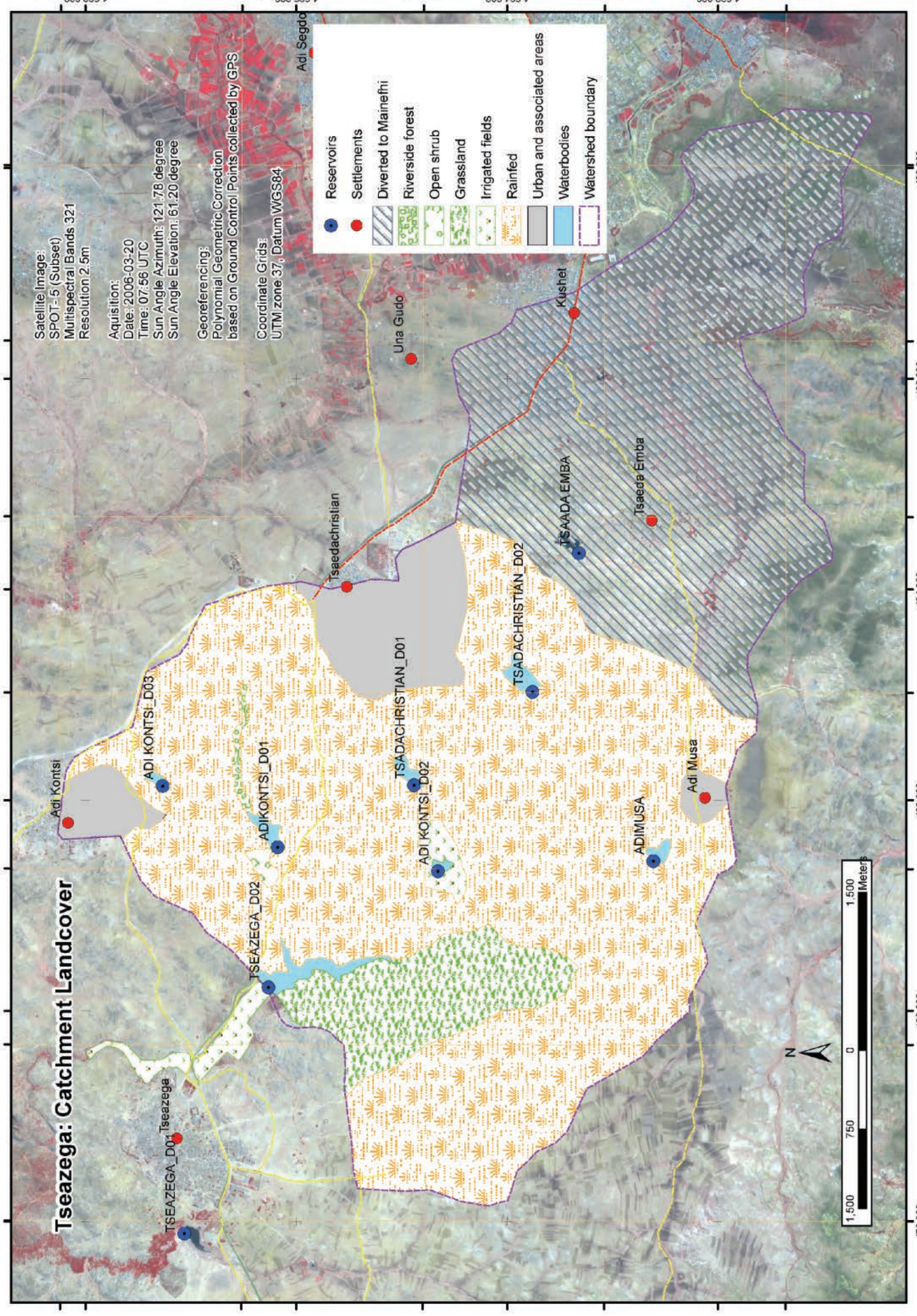
Type of Livestock	Daily water consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	1500	10,980
Sheep and Goats	2	4800	3,514
Equines	10	850	3,111
Total			**17,605**

Other uses

Reservoir water is used for house construction, a brick factory, and in flour mills.

Conclusions and Recommendations

- In other villages, once a dam is constructed the irrigable area is redistributed to every farmer equally. In Tseazega land reallocation has not been done for a longer period. In order to allow all villagers to benefit from the facility, the irrigable areas should urgently be redistributed.
- There is an urgent need for the establishment of a strong water user association to improve management of the dam, of the reserved water, and of the irrigation infrastructure so that the demands of the whole community can be met.



Map 4.6 Catchment land cover map of Tseazega dam

4.7 Lamza Dam

Lamza is a small village in Subzoba Galanefhi. Lamza dam was built in 1986 with a maximum height of 7.5 m and a capacity of 230,000 m^3. It was constructed by MoA and was rehabilitated in 1995, when its height was increased to 12.5 m and its capacity to 500,000 m^3.

General Information

Location: 37 491234 E,
16 83301 N
Date of construction: 1986
Constructed by: MoA
Design capacity: 500,000 m^3

Actual capacity: 442,780 m^3
Actual water volume at the time of survey: 25,612 m^3
Dam crest length: 201 m
Dam height: 12.51 m
Type of dam: Earth fill

Figure 4.8 Lamza dam and its surrounding catchment

Condition of Catchment

The catchment area of Lamza dam is mostly closure area covered with Acacia albida, remnants of Olea africana, bushes and grass. Sedimentation is minimal relative to other catchments.

Catchment area: 854 ha (8.5 km^2)
Slope: Mainly undulating to slightly steep; patches of flat or moderately steep slopes
Catchment land cover types: (See Table 4.18)

Table 4.18 Catchment Land Cover Types, Lamza

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	4.3	0.5
Rainfed Small Herbaceous Fields	303.8	35.6
Open shrubs	491.7	57.6
Urban and Associated Areas	53.8	6.3
Total	853.6	100.0

Irrigation

Lamza farmers' experience in irrigation dates back to the Italian colonial era. The current reservoir area was an Italian concession used to produce horticultural crops for Asmara some 70 years back. The source of irrigation was at that time a spring on the upper hill, the water of which was diverted to the fields. The farmers at Lamza worked as daily laborers. When the Italians left they started to grow horticultural crops themselves. Today, they grow about 23 different vegetables and spices. During the 1981-84 droughts the spring water dried up. A new dam was constructed as a source of water in 1986.

The irrigation intensity is 3 times per year. The land suitable for irrigation downstream o the dam is almost fully utilized. It seems small to the design capacity particularly when the dam is full. Yet Lamza has a good water management system and a strong water user association.

Number of beneficiaries: 120 households
Area of currently irrigated fields: 17.7 ha
Potential irrigable area: 43 ha
Main horticultural crops: (See Table 4.19)

Table 4.19 Horticultural crops grown in Lamza

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Carrot	50	June	Oct	360	5
Potato	15	June	Sep	180	10
Cauliflower	10	Any time	4 months	220	10
Tomato	5	June/Feb	Sep/May	285	5
Zuccini	5	Feb	April	198	7
Luttuce	3	Any time	3 months	200	8
Cabbage	5	Any time	4 months	414	2
Spice /sedeno	2	Any time	-	36	7
Spinach	5	June	Oct	145	10

Irrigation intensity: Three times per year
Irrigation interval: Once a week
Irrigation system: Furrow and basin
Water conveyance system: Open earth and lined channel
Physical properties of the soil of the irrigable areas: Loam to sandy loam
Frost occurrence: December - February

Market: Asmara
Percent of marketed produce: Over 90%
Production constraints: Lack of inputs mainly fertilizer, pesticides, and fuel for water pumps.

Domestic Water use

Domestic water is pumped from a well downstream of the dam to the village at a rate of 40 liters/family. The villagers fetch around 1,440 liters (24 jrba) of water per day from the dam for washing. In total, an estimated total of 2,284 m^3 of water is consumed for domestic purposes.

Livestock Watering

Type and number of livestock and their consumption is presented in Table 4.20.

Table 4.20 Type and number of livestock, Lamza

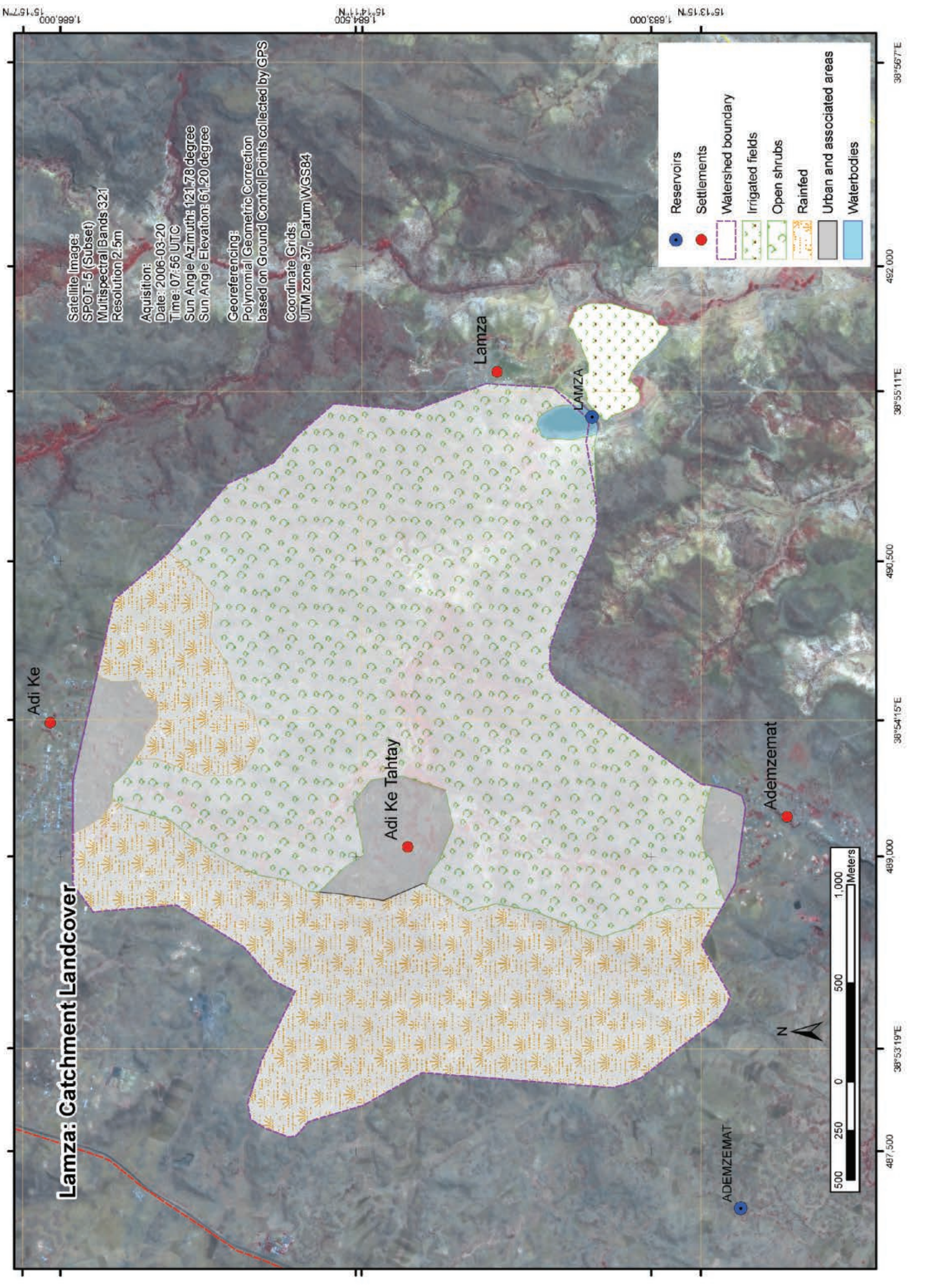
Type of Livestock	Daily water consumption	Total number	Water consumption per year (m^3)
Cattle	20	180	1318
Sheep and Goats	2	150	110
Equines	10	80	293
Total			1721

Other uses

No other use of reservoir.

Conclusions and Recommendations

- Expand irrigable area by leveling and terracing the marginal land around the dam.
- Introduce modern irrigation system to save water and energy, and to increase the size of the irrigable land.
- Strengthen the existing water user association by intensive training.
- Replace the existing diesel pumps by electric or solar pumps to reduce production (energy) costs.
- Improve the access road to the village.



Map 4.7 Catchment land cover map of Lamza dam

4.8 Laugen Adi Hamushte Dam

The dam is located in Subzoba Galanefhi. Constructed in 1995 by MoA, the rock fill dam of 22 m height has a capacity of 1,300,000 m^3. The dam is located between the villages of Laugen and Adi Hamushte and is shared between these two communities. Excessive seepage can be observed downstream of the dam.

General Information

Location: 37 482664 E,
16 83651 N
Date of construction: 1995
Constructed by: MoA
Design capacity: 1,300,000 m^3

Actual capacity: 1,031,791 m^3
Actual water volume at the time of survey: 114,202 m^3
Dam crest length: 190 m
Dam height: 22 m
Type of dam: Rock fill

Figure 4.9 Partial view of the Laugen Adi Hamushte dam during bathymetric survey

Condition of Catchment

Most of the catchment is terraced agricultural land, open shrub, or grazing land. Most of the terraces are well consolidated and grass-covered, though in some areas they require rehabilitation or maintenance.
Catchment area: 1,093 ha (10.93 km^2)
Slope: Flat to undulating
Catchment land cover types: (See Table 4.21)

Table 4.21 Catchment Land Cover Types, Laugen-Adi Hamushte

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	9.1	0.8
Irrigated Herbaceous Fields	18.4	1.7
Isolated (in natural vegetation or other) Rainfed Small Herbaceous Fields (Field frequency 10-20%)	144.1	13.2
Rainfed Small Herbaceous Fields	647.1	59.2
Open shrubs	177.6	16.2
Tree plantation	2.7	0.3
Riverside Forest	12.2	1.1
Urban and Associated Areas	81.8	7.5
Total	1093.0	100.00

Irrigation

The dam has an outlet split into two, one for each village, each connected to a main line of about 1000 m of galvanised iron piping. The irrigation potential of the dam at spillway level is 130 ha. Currently 28.6 ha are irrigated which is meagre in comparison, and which is due to excessive seepage from the dam, and to lack of proper management.

The water user association is practically non-existient. Currently, irrigation is managed by few farmers from both villages.

Number of beneficiaries: 470 households
Area of currently irrigated fields: 28.6 ha
Potential irrigable area: 120 ha
Main horticultural crops: (See Table 4.22)

Table 4.22 Horticultural crops grown in Laugen-Adi Hamushte

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Potato	30	Feb/ Sep	May/Nov	220	8
Tomato	30	Sep/ Feb	Nov/May	315	5
Cabbage	30	Any time	4 months	235	3
Luttuce	5	Any time	3 months	210	5
Alfa alfa	3	Any time	3 months	80/every month	-
Zuccini	2	Feb/ Sep	May/Nov	310	7

Irrigation intensity: Twice or three times per year
Irrigation interval: Once a week
Irrigation system: Furrow and basin
Water conveyance system: Earth channels and pipe system
Physical properties of the soil of the irrigable areas: Loam to sandy loam
Frost occurrence: December - February
Market: Asmara

Percent of marketed produce: Over 90%
Production constraints: shortage of Agricultural inputs like fertilizer, pesticide, sprayer, and irrigation infrastructure; weak water management system.

Domestic Water Use

None from reservoir.

Livestock Watering

Type and number of livestock and consumption are presented in Table 4.23.

Table 4.23 Type and number of livestock, Laugen-AdiHamushte

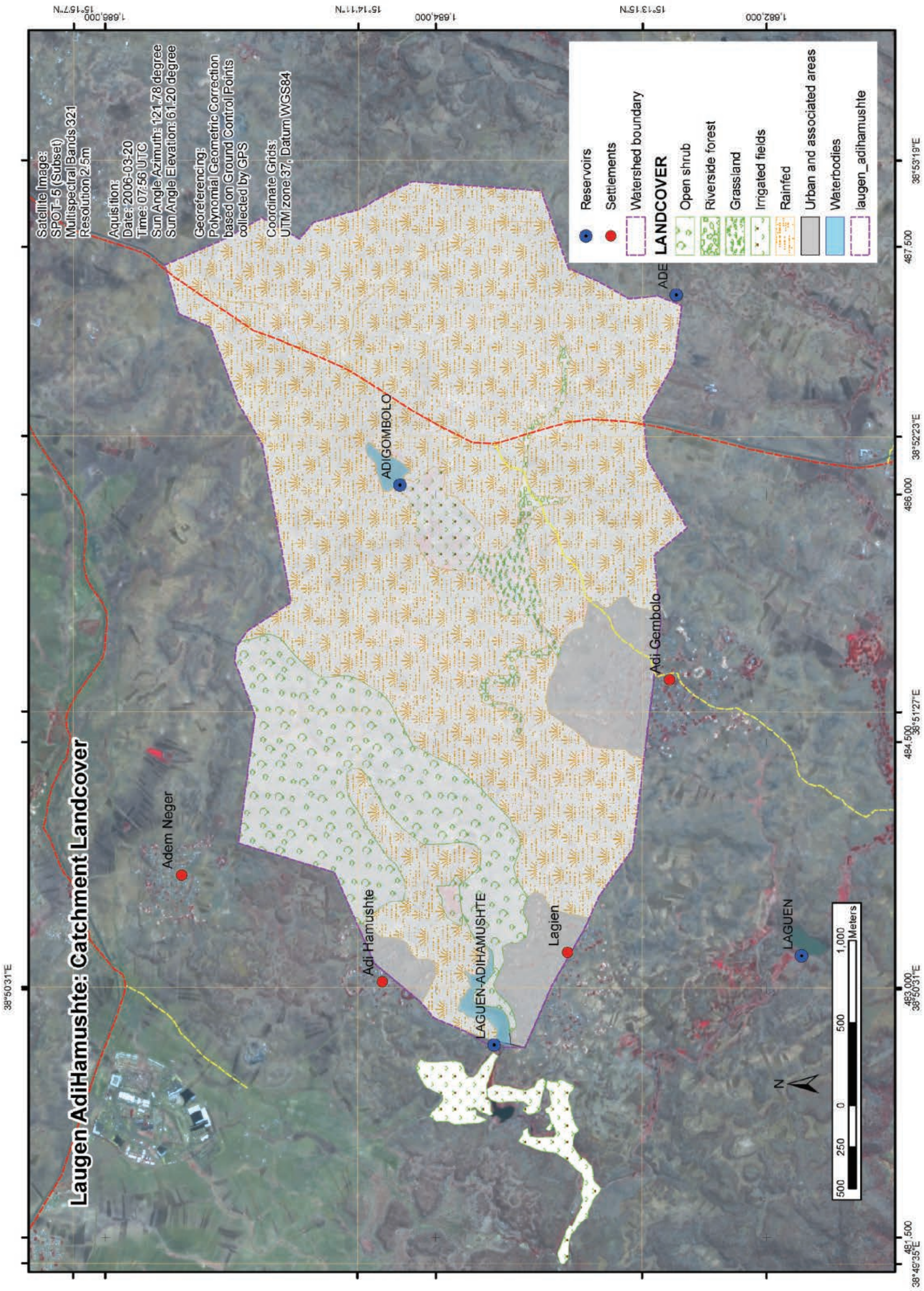
Type of Livestock	Daily water consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	350	2562
Sheep and Goats	2	1500	1098
Equines	10	250	915
Total			**4,575**

Other uses

No other use.

Conclusions and recommendations

- The water user association should be strengthened and equipped with full authority to manage the reservoir, dam and irrigation infrastructure in general and secure efficient water use.
- The dam requires maintenance to minimize seepage.
- A water and energy efficient irrigation technology needs to be introduced.
- The irrigation infrastructure has to be extended so as to cover all the potential irrigable area.



Map 4.8   Catchment land cover map of Laugen Adi Hamushte dam

4.9 Himbrti Gomini Dam

Himbirti is a village located in Subzoba Galanefhi. Himbrti Gomini dam was constructed in 1989, and rehabilitated and increased by 1.5 m in 2004. As a result its capacity increased to 450,000 m^3 and the reservoir area fro 9.9 to 11.8 ha.

General Information

Location: 37 474224 E,
16 89001 N
Date of construction: 1989
Constructed by: MoA
Design capacity: 330,000 m^3

Actual capacity: 337,829 m^3
Actual water volume at the time of survey: 66,208 m^3
Dam crest length: 229 m
Dam height: 11 m
Type of dam: Earth fill

Figure 4.10 View of Himbrti Gomini dam

Condition of Catchment

The catchment area is relatively stable, mostly terraced and planted with eucalyptus and Acacia saligna. Acacia albida is also regenerating. Land cover is characterized by stony hills relatively densely vegetated, by grazing land except for the upper part bordering Adi-Teklay, which is bare and rocky.

Catchment area: 1,129 ha (11.29 km^2)
Slope: Mainly undulating with small flat and slightly steep slope areas
Catchment land cover types: (See Table 4.24)

Table 4.24 *Catchment Land Cover Types, Himbrti Gomini*

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	4.8	0.4
Irrigated Herbaceous Fields	100.3	8.9
Rainfed Small Herbaceous Fields	884.9	78.4
Open Shrubs	79.9	7.1
Sparse Shrubs	16.7	1.5
Artificial water bodies	42.4	3.8
Total	1129	100.0

Irrigation

With the rehabilitation of the dam in 2004, a 1600 m PVC main channel with hydrants every 100 m was installed so as to reduce seepage losses, increase water use and power efficiency. The system was designed as a pilot to demonstrate modern water saving pressurized irrigation. The irrigation system is dominated by furrow and basin irrigation. Irrigation intensity is twice per year, but a few leading farmers grow up to three crops per annum.

Number of beneficiaries: 600 households
Area of currently irrigated fields: 42.9 ha
Potential irrigable area: 40 ha
Main horticultural crops: (See Table 4.25)

Table 4.25 *Horticultural crops grown in Himbrti Gomini*

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Alfa alfa	30	Any time	After 3 months	50	1.30
Cabbage	25	Dec	March	330	4
Onion	20	Oct	Feb	200	7
Potato	10	Feb	May	190	10
Tomato	10	Feb	May/June	325	5
Garlic	5	Nov	Feb	100	40

Irrigation intensity: Twice or three times per year
Irrigation interval: Once a week
Irrigation system: Furrow and basin
Water conveyance system: Pipe channel
Physical properties of the soil of the irrigable areas: Loam to silty loam
Frost occurrence: December – February
Market: Asmara
Percent of marketed produce: Over 90%
Production constraints: Shortage of agricultural inputs such as fertilizer, pesticides; fuel etc.; shortage of water, lack of agricultural extension services, and unleveled land.

Domestic Water Use

None from the reservoir.

Livestock Watering

Type and number of livestock and consumption rates are presented in Table 4.26.

Table 4.26 Type and number of livestock, Himbrti Gomini

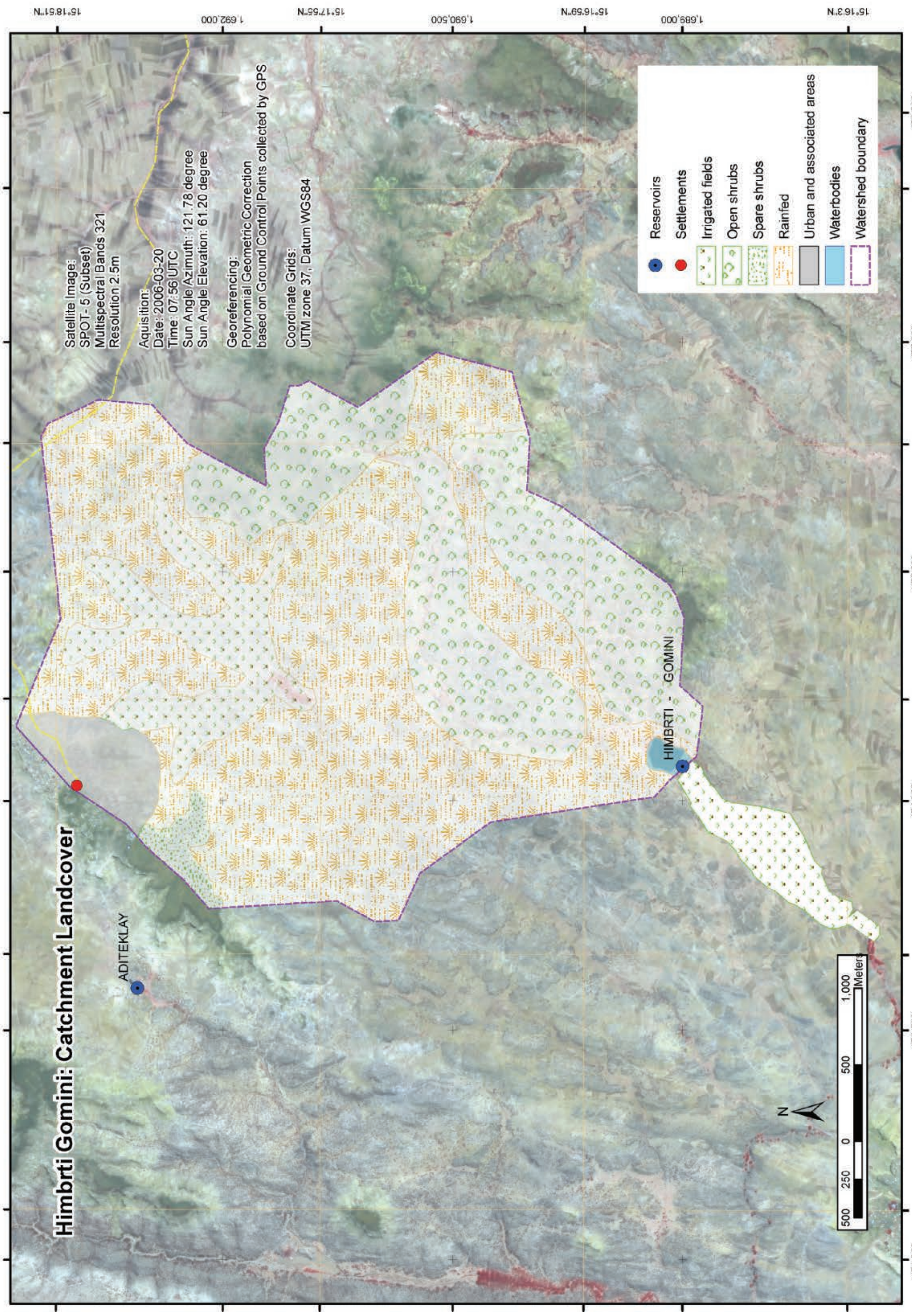
Type of Livestock	Daily water consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	3400	24,888
Sheep and Goats	3	1000	1,098
Equines	10	100	366
Total			**26,352**

Other uses

No other uses of reservoir water.

Conclusions and Recommendations

- Inspite of considerable investment and resource endowment (land), irrigation de development was not encouraging in the past 19 years. This is mainly due to a weak water user committee. The committee should be strengthened to manage the whole system, including the reservoir, the dam body and the irrigation infrastructure. Most importantly, it should ensure efficient use of water.
- To minimize contamination, animals should be prohibited from use reservoir water directly; troughs should be built for watering downstream of the dam.
- The reservoir should be fenced in (biological or or other methods) and a permanent guard employed to look after the whole system.
- Crop selection can be improved to use water more efficiently.



Map 4.9 Catchment land cover map of Himbrti Gomini dam

5 Conclusions and Recommendations

5.1 Conclusions

Water productivity optimization can be used as a strategy for allocating scarce water resources to attain optimum societal benefits. A water productivity strategy, however, should be based on holistic information about the resources available and include wide stakeholder consultations to derive the optimum societal benefits.

This study aims to contribute to a water productivity strategy by providing sound information on water resources, irrigation practices, and ways of developing irrigation in Eritrea. For this purpose, the study considered physical characteristics as well as societal traits such as stakeholders' perceptions and aspirations, also at the village level. Its focus is on Zoba Maekel and Upper Anseba Catchment, where competition for water is most pronounced, at least in relation to the highlands.

In a first phase, a reliable and above all holistic database was developed on the current status of reservoirs, their corresponding catchment areas, downstream irrigation activities, and other competitive water uses. A survey of the 74 reservoirs in Zoba Maekel (including one in DekiZeru, Zoba Anseba) showed that an estimated 67 million m^3 of water can be stored in these facilities, of which 32 million m^3 in 49 dams in Upper Anseba Catchment. This shows that the potential for surface reserved water in Zoba Maekel, and particularly in the Upper Anseba Catchment, is very substantial and requires special attention. The information collected by this inventory is a first step in prioritizing areas of intervention and identifying areas of further investigation.

Reservoirs may not be sustainable, as they eventually lose their storage capacity by filling up with sediments. A detailed survey of nine reservoirs and their corresponding catchments revealed that the dams are losing storage capacity at a rate of 0.5 – 2% annually. This estimate was based on comparison of the design (original) capacity obtained from the archives of the MoA and the current or actual capacity obtained through a reservoir resurvey. Results from the catchment characterization showed that sediment yield varies from one catchment to the next, from 262 t/km^2/year in Hayelo-Geshnashm to 1769 t/km^2/year in AdiAsfeda, with an average of 856 t/km^2/year. On the other hand, the sediment deposition data obtained from the bathymetric survey shows that specific sediment yield ranges between 132 m^3/km^2/yr and 1846 m^3/km^2/yr, with a mean value of 703 m^3/km^2/yr. The MoA is trying to remedy the problem by rehabilitating the dams by increasing their height but this entails extra costs that could be avoided or reduced if siltation rates can be reduced in future.

An attempt was made to estimate the reservoir capacity within the Upper Anseba Catchment. Based on the potential (design) capacity of the dams, this figure is 32 million m^3 of water. As 88% of the dams were constructed more than a decade ago, their silt load is considerable and amounts to 23% of the design capacity, according to the results obtained from this study. The current reserve capacity in this catchment is therefore around 24.5 million m^3. This value corresponds to about 70% of the annual water yield from rainfall received over the whole catchment.

The groundwater potential is difficult to assess, as information relating to its residence time in the basin is largely lacking and is difficult to assess due to the geology of the area, which is dominated by highly fractured metavolcanic rock. Meticulous efforts will be required in future to understand the potential of the groundwater and the potential groundwater reservoir in this area. Nonetheless, the recharge rate derived from the catchment water balance undertaken in this study indicates that on average, 11% of the rainfall percolates into groundwater. Assuming a uniform rate of recharge over the whole catchment, the yearly groundwater recharge is about 23 million m^3 of water.

This study also found that the total area currently irrigated within the Upper Anseba Catchment is 322 ha. The corresponding figure for Zoba Maekel is 487 ha, of which 447 is irrigated from class one reservoirs, and the rest from class two reservoirs. The total number of beneficiaries in the Zoba was estimated to be 11,720 households, which corresponds to all rural households in villages with access to a dam. Based on an average household size of 4.5 persons (NFIS 2005), the number of beneficiaries is therefore about 54,000. This is 38% of the rural population of Zoba Maekel; for Upper Anseba, this figure is as high as 61%.

The potential irrigable area in Zoba Maekel was calculated to be 1082 ha. This value is based on design capacities. When siltation losses are taken into account, this figure drops to 833 ha (of which 475 ha are in Upper Anseba). Compared with current use, there is thus considerable potential for expansion of irrigation. Overall, an additional 346 ha can be irrigated using reservoir water. For Upper Anseba, the figure is 129 ha.

Remotely sensed satellite images and GPS data analysis using GIS helped to provide an accurate estimation of the current irrigated fields in nine selected reservoirs for which an indepth survey was done. Even though the area irrigated by dam water has been increasing in recent years, development is still not satificatory compared to the number of reservoirs and the aggregate volume of reserved water. In view of the inadequacy and unreliability of rainfall in Eritrea, irrigation will have to play a more important role in improving crop production and food security. Thus, much remains to be done to use available water resources efficiently and sustainably.

Inefficient irrigation not only wastes water and other resources, it can also leach off important nutrients from the topsoil. If insufficient water is applied, on the other hand, crops will be affected. Therefore, a critical element in irrigation management is when to irrigate and how much water to apply. This requires basic knowledge and understanding of soil-water-plant relationships. In this study a set of climatic, soil and crop data have been used to estimate the crop water requirement of four common crops grown in the highlands (potato, tomato, carrot and cabbage). The resulting weekly water budgets can be used for irrigation scheduling. Considering the waste of water under current irrigation practices, there is an urgent need to introduce irrigation scheduling. The calculations presented in this study can serve as a pilot for a scheduling regime.

31 reservoirs were identified as class one reservoirs within the study area. These reservoirs are active in irrigation and the efficiency and utilization of water is better in these reservoirs relatively speaking. These reservoirs were ranked as 1, 2 and 3 (Table 5.1), based on current irrigation activities, the strength of water use associations, and the unit agricultural production per m^3 of water used by the respective villages. The villages with

reservoirs that have a ranking of 1 can therefore be taken as role models, and their experiences shared with the other villages by organizing farmers' field days or any other form of exchange that helps create awareness of the potential and the opportunities represented by a well-managed irrigation system.

Table 5.1 Class One Reservoirs for irrigation priorized into three classes

S.No	Reservoir	Year of Const.	Design Capacity (m³)	Current Irrigation (ha)	Potential Irrigable (ha)	Priority Class
1	Hazega	1982	40,000	7	4	3
2	Tseazega	1988	453,420	33.5	45	1
3	Shinjibluk	2007	350,000	10	35	2
4	Adi Kontsi	1970	250,000	2	25	2
5	Ametsi	1988	180,000	30	18	1
6	Adi Asfeda	1988	200,000	32	20	1
7	Adi Habteslus	1941	80,000	4	8	3
8	Adisheka	Before 1930	5,100,000	12	20	2
9	Adikolom	1989	270,000	5	27	3
10	Embaderho	1992	330,000	24	35	1
11	Guritat	2006	300,000	6	30	1
12	Hayelo	1995	1,000,000	40	100	1
13	Mekerka	2003	270,000	16	27	1
14	Mesfinto	1995	60,000	9	6	1
15	Shmangus laelai	1985	400,000	15	40	2
16	Shmangus Tahtai	1992	230,000	15	23	2
17	Teareshi	1989	280,000	11	28	2
18	Adi Nefas_D01	Before 1930	600,000	30	–	3
19	Adi Nefas_D02	1941	200,000	20	–	1
20	Daero Paulos	1987	60,000	2	6	3
21	AdiGhebru-AdiTeklay	1985	160,000	6	16	3
22	Tselot_D03	1989	250,000	2	25	2
23	Tselot_D02	2005	300,000	3	30	2
24	Adi-Ahderom	2007	250,000	12	25	1
25	Laguen-AdiHamushte	1995	1,300,000	29	130	2
26	Himbrti Shaka	1985	400,000	11	40	2
27	Himbrti Gomini	1989	450,000	15	45	3
28	Laguen	1987	200,000	15	20	1
29	Adi Gombolo	1982	150,000	7	15	2
30	Adi Hawesha	1988	150,000	5	15	3
31	Lamza	1986	500,000	18	50	1

Reservoirs assigned Serial No 1-19 are situated within the Upper Anseba Catchment, while the rest are outside of the catchment but located within the Administrative boundaries of Zoba Maekel.

Participatory Rural Appraisal (PRA) and group discussions were also carried out in order to gain insight into the perceptions and ambitions of the communities regarding reservoirs. Prioritization of activities and their contribution to household incomes indicate the commitment of the villages to specific activities. The higher the income from an activity, the greater the commitment to that activity. The study team found it unusual that the communities put financial and material resources at the end of the priority list. This may indicate relatively low economic disparity among the rich and the poor within village communities.

In concrete terms, all villages mentioned water and shortage of land as the main constraints on irrigation. The second and third major constraints were insecure land tenure and limited supply of improved seed, fertilizer and pesticides. Lack of markets, transportation problems, and shortages of irrigation equipment were also mentioned as problems. In sum, the problems added up to substantially constraints on irrigation and thus limit the benefits that could be obtained from this activity.

A by-law prepared by the Maekel branch of the MoA is the only currently available official regulation related to water management. It aims to ensure efficient use of dams and their downstream irrigable areas in the Zoba, including Upper Anseba. The by-law has been in effect since June 2004. Its positive and negative impacts were evaluated during the field survey in discussions with villagers and administrative staff.

5.2 Recommendations

The following recommendations can be made from the study:

- The study provided a wide range of information on the number and distribution of reservoirs in Zoba Maekel and specifically in the Upper Anseba Catchment. Design and actual capacities were estimated, siltation rates assessed, and the irrigation activities in the area studied in detail. This valuable information can be used to improve food security in the area by optimizing dam water management and water use in a sustainable way.

- Though it is difficult to propose the construction of new dams in Upper Anseba such a way as not to cut off water supplies to existing dams, and to reduce river run off to downstream areas below critical levels, it is possible to come up with recommendations for upgrading the reservoirs and securing efficient use in those that exist already. Table 5.2 prioritizes reservoirs into three classes relating to development priority. Priority is based on current good performance; development efforts to improve this performance differ according to reservoir and village, and relate to maintenance, efficiency of water use, institutional improvements (strength of water committees), and supply chains for agricultural production.

Table 5.2 Priority list of reservoirs for future development in Zoba Maekel A

A. Development Priority for Class One Reservoirs

S.No	Name of Dam	Capacity (m^3)	CIA	PIA	Beneficiaries	Year of Cons.
1	Lamza	442,780	20	43	196	1986
2	Ametsi	118,000	45	12	230	1988/2004
3	AdiAsfeda	200,000/365,755	25	30	210	1988/2002
4	Embaderho_D01	330,000			300	1965-70
5	Mekerka	270,000	16	27	350	2003
6	Tseazega	230,000/453,421	25	36	750	1988/2000
7	Hayelo-Gheshnashm	1,000,000	23	90	224	1995/1997
8	Laugen	200,000	15	20	567	1987
9	Mesfnto	80,000	9	9	123	1995
10	Laugen-AdiHamushte	1,300,000	20	120	913	1995
11	Himbrti -Shaka	400,000	11	35	1410	1985
12	Shmangus tahtai	230,000	15	23	120	1992
13	Shmangus laelai	400,000	15	20	350	1985/2006
14	Guritat_D01	300,000	6	24	200	2006
15	Taareshi	280,000	11	20	198	1989
16	Himbrti -Gomini	450,000/337842	6	40	1410	1989/2004
17	Shnjibluk	350,000	10	35	185	2006/07
18	AdiAhderom	250,000.00	12	30	185	2006/07
19	Adikolom	270,000	5	26	490	1989
20	Tselot_D	250,000		25	960	2007
21	Kodadu	700,000		70	449	1995/6
22	AdoGombolo	150,000	7	15	316	1982

B. Development Priority for Class Two Reservoirs

S.No	Name of Dam	Capacity (m^3)	CIA	PIA	Beneficiaries	Year of Cons.
1	AdiHawesha	150,000	5	23	406	1988
2	Tseazega	150,000		15	750	1983
3	Zagr	150,000	2	15	814	1984
4	AdiKontsi	250,000	2	25	388	1970/ 2007
5	AdiSheka	5,100,000	12	20	213	<1930/1986
6	Tselot	300,000	3	30	960	2005
7	Tselot	250,000		25	960	2007
8	Himbrti-Chea	150,000	2	15	1410	1986
9	AdiKntsi-AdiYakob	200,000		20	250	2007
10	Adi Ghebru-Adi Teklay	160,000	6	16	300	1985

11	Hazega	250,000	Livestock, DU	20	250	1989
12	Tsaedachristian	130,000	Livestock, DU	12	400	1983
13	DaeroPaulos	60,000	2			1987
14	AdiHabteslus	80,000	4	8		1941
15	Adearada	200,000	3	20	260	2006/07
16	Guritat_D02	180,000	3	18	220	1997

C. Development Priority for Class Three Reservoirs

S.No	Name of Dam	Capacity (m^3)	CIA	PIA	Beneficiaries	Year of Cons.
1	Adibide	90,000	9		235	1988
2	Adimerawi	110,000	3		80	1992
3	Hazega	40,000	7		250	1982
4	Tsaedachristian	80,000	4	8	400	1944
5	Adimusa	250,000	2.5	25	150	1992
6	Aditeklay	53,000	3	6	150	1988
7	Adighebru	80,000		8		2000
8	Tsaadaemba	55,000	2.5	6	250	1980
9	Wokiduba	25,000	Livestock, DU		350	1985
10	AdiKontsi	70,000	Livestock, DU	7		1970
11	AdiKontsi	50,000	Livestock, DU			1970
12	AdiYakob	80,000	3	8	200	1993
13	Adisegudo	120,000	4	12	220	1983
14	Tselot	50,000		5		1984
15	Tselot	250,000	2			1989
16	AdiKeih	40,000.00	Domestic use		50	2007
17	Embeito	130,000	Livestock, DU	10	282	1993
18	Merhano_D01	250,000		25	334	1988
19	Merhano_D02	60,000				1998
20	Adiguadad	150,000	Livestock, DU	15	520	1981
21	Selaadaro	80,000	6	8	245	1981
22	AdiKeshi	250,000	2	20	102	1988
23	Ademzemat	50,000	Domestic use		200	2006
24	Embaderho_D01	60,000			100	1965-70
25	AdiAbeyto	110,000	Livestock, DU			1985

DU- Domestic Use
CIA, PIA – Current / Potential irrigable area

- The study demonstrates the value of comprehensive information on natural resources such as reserved water as a tool for optimizing land-use and management strategies. Specifically, it can help devise strategies for tackling reservoir sedimentation in the highlands of Eritrea and provide a basis for proposing land management options for efficient water use and for shaping food security plans and strategies.

- There is a great deal of local information and knowledge which policy-makers including the Ministry of Agriculture need to build on; institutions should invite farmers to be part of the problem identification and development process.
- This study identified catchments in need of urgent soil and water conservation in a bid to reduce siltation rates and obtain a reasonable dam life. Generally, it is necessary to carry out maintenance and long-term soil and water conservation activities in all catchments. It is also proposed that land redistribution should be extended to cover a longer period than the 7 years currently practiced, in order to motivate farmers to make long-term investments.
- Siltation as a serious problem relating to reservoirs should be discussed within a coordinated technical, institutional and legal framework that integrates all stakeholders concerned. Alongside soil conservation, desilting and dam scooping might be effective alternative approaches for maintaining storage capacity.
- Agricultural inputs such as seed, fertilizer, and plant protection chemicals should be made available at affordable prices to farmers again. In addition, it is important to establish appropriate marketing and credit services to encourage farmers.
- The irrigation system in the area is still traditional and it is clear that such a system does not allow for efficient and sustainable use of water. Thus, improved irrigation management is urgently required. Specifically, there is an urgent need to implement irrigation scheduling. Another way of improving the efficiency of water use is to replace open furrows with piped channel systems to improve conveyance of water to the irrigated fields.
- Most of the villages in the study area produce two irrigated crops per year, as it is not common to grow crops during the coldest months of the year, i.e. from November to January. But frost-tolerant crops could be grown in this period, making use of reserved water before it evaporates. Crop selection for identifying crops that demand less water would help increase production per m^3 of water used.
- The study area is close to Asmara, the capital of Eritrea and by far the greatest urban area in the country. These are favorable conditions for marketing. Efforts should be made to improve access to this large market by improving rural road access necessary.
- The spatial coverage of meteorological stations was found to be insufficient for adequate modeling. It is therefore recommended that additional stations be installed in the catchment.
- Animals should not be watered directly from the reservoirs; it is recommended that troughs be installed on the downstream side of the dams.
- The creation of effective community water management committees needs to be given top priority. Establishing water user associations and strengthening institutional and organizational structures through training and provision of incentives is very important. Comprehensive water use by-law should be prepared. It is also highly advisable to prepare a coordinated water use and development master plan at catchment level.
- In order to supplement the reserved water in the dams, it is necessary to exploit other sources of water such as fog harvesting, roof catchment water harvesting, and others.

- Awareness creation and exchange between policy-makers, villagers, and administrators is essential to achieve sustainable land and water development in Upper Anseba Catchment. Capacity development for farmers and extension agents could be promoted through training, farmers' days, and field visits to villages with good or exemplary irrigation practices such as those identified as Class One Reservoirs earlier in this chapter.
- Standardization of methodologies for assessing and predicting sediment yield and for irrigation scheduling should be developed as a top priority.
- Although this study was predominantly concerned with quantitative analyses, semi-quantitative expert-based techniques were employed to determine the severity of sedimentation, the efficiency of irrigation systems, water balance, catchment reserve capacity, and crop water requirements for selected crops. In future, more detailed quantitative assessments will need to be done. Further research is needed on reservoir siltation rates over time. This includes in-depth research on the factors causing siltation.

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7 Appendices

Appendix 1: Mean Annual Rainfall in mm for Selected Stations (1997-2007) in Zoba Maekel

Stations	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average
Bet Giorgis				365.5	603.9	372.4	394.7	288.1	485	642.1	575.2	465.9
Adi Nefas							393.7	294.4	590.1			426.1
Tsaedachristian	717.3	439.8	332.4	499.6	530.6	383.8	366.9	301.1	498.6	391.9	409.2	442.8
Tseazega	556.5	343.3	243.1	351.2	506.0	221.8	278.6	292.4	378.1	368.5	401.3	358.3
Hazega	591.0	344.0	295.5	531.7	819.3	380.3	422.1	296.1	541.2	398.5	473.6	463.0
Afdeyu	648.0	618.8	601.9	407.1	625.9	179.5	405.6	430.8	324.0			471.3
Hayelo				388.0	564.4			351.4				434.6
Geremi				568.2	607.9	220.7	415.5	421.1	630.0			477.2
Embaderho				372.6	814.0	327.8	383.2	391.8	463.9	405.9	533.1	461.5
Serejeka				436.0	576.0	273.1	397.1	413.7	587.5	617.4	349.0	456.2
Adi Hawesha	450.7	364.4	249.5	372.2	364.2	339.3	208.5	156.2	402.9	466.2	353.8	338.9
Merhano				311.6	449.0	341.3	375.4	277.4	479.8	416.6	423.3	384.3
Selaedaero				287.7	475.8	249.3	294.5	230.5	429.2			327.8
Himbrti	416.7	409.3	269.4	335.6	526.5	275.3	417.5	278.2	391.5	288.9	222.5	348.3
Tredishi				108.9	190.2	40.0	126.0	21.0				97.2
Average	563.4	419.9	332.0	402.1	574.1	297.1	365.6	315.9	477.1	444.0	415.7	418.8

Source: MoA-Zoba Maekel

Appendix 2: Techniques of Data Collection

Section 1: Questionnaire

An Appraisal of the Current Status and Potential of Surface Water in the Upper Anseba Catchment	Questionnaire No. ________ Date: ____________________

General information

1. Name of dam (if applicable): ____
2. Village name: ____
3. Administrative village: ____
4. Subzoba: ____
5. Location in UTM: E ____
   N ____________________
6. Date of construction: ___________________
7. The dam was constructed by:
MOA b. NGOs c. Community d. Other, specify ____________________________
8. Purpose or use:
Irrigation b. Domestic c. Livestock d. Fishing
Other, specify____________________
9. Current use if different from the purpose: _____________________________
10. Condition of the dam:
Functional b. Not functional
If not, why? (Silted or not, or if damaged or not)
____
11. Type of dam:
a. Earthen b. Masonry c. Rock d. Other, specify _______________________
12. Spill way type
a. Natural b. Retaining wall c. Weir
d. Other, specify _________________________________

13. Is there any possibility of upgrading? Yes or No
If yes how? ______________________________

Reservoir water actual and potential use

13. Where are the irrigated fields located?
a. Downstream of the dam b. Upstream of the dam

14. What is water-lifting mechanism (Water conveyance system) in the area?
a. Electric pump b. Shadoff c. Diesel pump d. Petrol pump
Specify the number and type of pumps: _______________________

15. The type of irrigation system practiced in the area:
a. Furrow b. Spate c. Sprinkler d. Basin d. Other, specify
____

16. Water conveyance system
a. Open channel b. Lined channel c. Pipe channel d. Other, specify
____

17a. Common horticultural crops grown:

Type of crops grown	Planting time	Maturing time	Production per ha	Average Price/Kg	Irrigation intensity

17b: Where do you sell your produce and how much is consumed at home, and how much is sold (%, estimate)? ____

18. Is there any frost occurrence? Yes/ No

19. If yes, when? From ________________ to_________________ (Date and month)

20. Does the frost occurrence have any negative impact on irrigated crops?
Yes or No

21. How is the irrigation timing or intensity? ______________Days/ week

22. If the dam is used for domestic purposes, is it for rural or urban water supply? ____

23. How do you access the dam water for domestic use?
a. Well on downstream
b. Direct from dam

24. How do you water your livestock?
Directly from the dam
Using basins or watering points
From wells dug downstream from the dam
25. Is there any industrial activity related to the dam water use? If yes, what type of activity ____________________________________

Community ambition and perception
26. What is the most important infrastructure you have in the village? Prioritize
School ()
Clinic()
Dam()
Water supply system()
Sanitation facility()

27. What is the most important contribution of the dam in your life?
Irrigation only
Animal watering only
Good name only (pride)
Fishing
Combination of all
28. Do you think what you have got what expected to get from your dam?
Yes
No
In the middle, why? ______________________________________
29. Do you think you are using the water from the dam efficiently?
a. Yes
b. No why? ___________________________________

30. Do you have any regulation on the use of water from the dam?
Yes, any reservation? Why?

____

No, do you think you need one? Why?

____

31. What do you think should be done for future to improve efficiency?

____

____

32. Do you have any fear or concern that might hinder the well being of your dam?
No
Yes, what?

____

____

Section 2: Interviews

Interview with administrator, water committee or development committee

Who uses the water from dam? Name all the users (stakeholders) including groups who use for irrigation, domestic purposes, industrial uses (making bricks and others), fishing, recreation activities (including swimming and fishing), and watering animals and so on.
What is the water from the dam used for? Name all use of water from the dam?
Is there any dedicated body or committee to administer or manage water resources in the village?
If there is a committee, who elect the committee? How many are the member of the committee? What is power extent?
Who decides on the allocation of water resources from the dam? How are the community of the village and other several stakeholders involved?
How is allocation of resources across sectors, users and time made? What are important factor? Or what is the priority?
Do users pay for water from the irrigation?
Who protects the water source in case of improper use (like for example pollution factor, overuse or foreign intervention (use)?
How large is the area of irrigated field allocated for each farmer (in hectares or tsmdi)?
Is there any fishing activity? If yes when was it introduced and do you think that it has any economic benefit?

Informal interview to farmers:

How much water (average) do you use over a period of time?
Do you have any water shortage for irrigation or other purposes from the dam, across all seasons?
If there is shortage of supply, what do you think is the reason? Over usage, poor management, low efficiency, small reserve capacity of dam. (Subjective question)
Do you pay for the water you use from the dam?

Interview with government offices, group discussion, and literature review

What is the extent of the current irrigated fields?
Who manages water in the upper Anseba catchment? Who approves dam construction or any other water extraction facilities?
Any knowledge of bylaws? If yes, how was your institution participation in drafting the document?
How are issues or competition resolved across ministries for different uses, (agricultural, domestic, industrial uses)? Who is in control and how are activities and needs integrated?
Is there any an established regulation or procedure o construct a dam in this catchment?

Focus Group discussion points

(The questions here can be added or deducted according to the reason of selection of the case study)
What was the village involvement in the planning, design and implementation of the dam?

How is the dam importance rated when compared with other infrastructures?
How efficient do you think you are using your water?
Who manage the water from the dam (allocation and protection the safety of users and the dam)
Do you have any regulations? A Village dam management institution? If no, why not? If yes: does it work? If no: why not?
Do you think you should pay for water from the dam? Why? *Or: Why not (gift of god….)?*
What impacts have you seen due to the upstream dam construction?
What are the factors (land, water or other impacts) of conflict? How do you think you will solve this issue?
Do you have any bylaws? Did you find it workable? What do you think about it?

Section 3: Checklist for field observation
Condition and extent of irrigated fields
Water conveyance system and its state
Soil type and condition in irrigated fields
Horticultural crops, their status and disease occurrence
Fishing in reservoirs
Catchment treatment: SWC measures and occurrence of erosion hotspots
Reservoir key values: - has the dam water permanently throughout the year?
- how much, at maximum (m3, estimated), in which month?
- how much, at minimum (m3, estimated, in which month?

Appendix 3: Catchment Characterization Form

Factor	**Extreme**	Score	High	**Score**	Normal	Score	Low	Score
Soil type	No effective Plant cover, Either rock or thin Shallow soils	40	Poorly drained compacted soils, Much ponding on soil surface after Heavy rains	30	Moderately well drained medium textured soils, Some ponding on soil surface after heavy rains	20	Well drained coarse textured soils, little ponding on soil surface after heavy rains	10
Vegetation condition over whole catchments	Little effective plant cover, ground bare or very spare cover over 80%	40	Fair cover >50% of catchments is cultivated with annual crops	15	Good cover 20%-50% of catchments is cultivated with annual crops	10	Excellent cover<20% of the catchments is cultivated with annual crops	5
	Over 80%		<30%of Catchments is under Good grass cover or protected forest cover	15	30-60% of catchments is under good grass land or protected forest cover	10	>60% of catchments is under well maintained grassland /or protected forest cover	5
Sign of active soil erosion	Many actively eroding gullies draining directly into dam and /or water courses; active under cutting of river banks along main water courses	40	Some actively eroding gullies draining into dam and/or water course; little under cutting of river banks along main river water courses	20	Few actively eroding gullies draining directly into dam and /or water courses; no under cutting or river banks along main water courses	10	No actively eroding gullies draining directly in to dam and /or water courses; no under cutting of river banks along main water courses	5

Appendix 4: Characteristics of Surveyed Reservoirs

A. Characteristics of surveyed reservoirs in Upper Anseba Catchment

	Location (Zone P 37)										
RESERVOIR	X-UTM	Y_UTM	Year	**CONST. BY**	**DC (M^3)**	**CL (M)**	**DH (M)**	**CA (HA)**	**CIR (HA)**	**PIR (HA)**	**HH**
Adikolom	480841	1714035	1989	ERRA	270,000	165	10.5	383.5	5	27	490
Adisheka	488407	1712801	Before 1930	Italians	5,100,000	403	20	3741.7	12	20	213
Beleza	491141	1704784	1958	Italians	1,200,000	120	12	597.4	-	-	-
Embaderho_D01	488655	1705052	1992	Evangelical	330,000	180	8	239.2	24	33	300
Embaderho_D02	489084	1704885	1965	Private	60,000	73	6	179.8	-	-	100
Guritat_D01	482488	1719380	2006	MoA	300,000	120	11	306.6	6	30	200
Guritat_D02	483941	1718483	1997	MoA	180,000	96	10	223.0	3	18	200
Hayelo	482621	1716791	1995	MoA	1,000,000	80	18	1035.4	40	100	438
Mekerka	483629	1709868	2003	MoA	270,000	100	12	825.9	16	27	350
Mesfinto	486300	1712087	1995	Kale Hiwet	60,000	73	8	97.8	9	6	123
Shmangus laelai	484236	1711011	1985	MoA	400,000	230	9	705.2	15	40	350
Shmangus Tahtai	479493	1713149	1992	Evangelical	230,000	130	8	876.6	15	23	120
Teareshi	481613	1709749	1989	Evangelical	280,000	80	8	1341.1	11	28	198
Zagr	488333	1718554	1984	MoA	150,000	101	7.5	284.4	2	15	814
Adi Merawi	483975	1699660	1992	MoA	110,000	132	8	29.2	3		80
Hazega	482109	1701803	1982	MoA	40,000	45	6	129.4	7		250
Hazega	480910	1703668	1989	MoA	250,000	91	7	123.7	-	25	250
Tseazega	480226	1696267	1988	Evangelical	230,000	230	10.5	3761.7	33.5	23	750
Tseazega	477888	1697066	1983	MoA	150,000	213	8	946.2	-	15	750
TsaedaChristian	483027	1693762	1983	MoA	130,000	200	7.5	184.5	-	13	400
TsaedaChristian	482145	1694886	1944	MoA	80,000	114	6	228.8	4	8	400
Adi Musa	481423	1692616	1992	MoA	250,000	150	8	514.1	2.5	25	150
Adi Ghebru	474135	1696085	2000	Villagers	80,000	90	12	188.2	-	8	655
Tsaeda Emba	484346	1693322	1980	Villagers	55,000	120	5	68.1	2.5	6	250
Wekiduba	488616	1698799	1993	MoA	220,000	226	7	134.5	-	22	350
Shinjibluk	484497	1702572	2007	KR2/MoA	350,000	148	11	232.6	10	35	185
Adi Bidel	478139	1707709	2007	KR2/MoA	90,000	73	9	91.8		9	235

	Location (Zone P 37)										
RESERVOIR	X-UTM	Y_UTM	Year	**CONST. BY**	**DC (M^3)**	**CL (M)**	**DH (M)**	**CA (HA)**	**CIR (HA)**	**PIR (HA)**	**HH**
Adi Kontsi_D01	481555	1696180	1970	Villagers	250,000	160	7.5	451.8	2	25	388
Adi Kontsi_D02	481328	1694660	1970	Villagers	70,000	270	4	287.8		7	388
Adi Kontsi_D03	482137	1697270	1970	Villagers	50,000	131	5	85.5			388
Adi Kontsi/ Adi Yacob	480222	1699695	2007	KR2/MoA	200,000	93	10.5	118.6	-	20	250
Ametsi	485355	1706555	1988	ECS	180,000	116	10	166.0	30	18	230
Adi Asfeda	484950	1700905	1988	MoA	200,000	120	11	785.8	32	20	210
Adi Yacob	482128	1700369	1993	MoA	80,000	116	8	133.3	3	8	200
Toker	482403	1706782	2000	Municipality	14,000,000	285	73	14135.8	-	-	
Adi Habteslus	486247	1700699	1941	Italians	80,000	157	8	489.1	4	8	170
Adisegudo	490128	1697030	1981	MoA	150,000	120	7	521.3		-	
Tselot_D04	495318	1690282	1984	MoA	50,000	160	8	15.5	-	5	519
Merhano_D02	492125	1690028	1988	MoA	60,000	208	6	753.2	-	-	334
AdiNfas_D01	493423	1700860	Before 1930	Italians	600,000	190	10	389.2	30	-	300
AdiNfas_D02	493225	1703000	1941	Italians	200,000	191	9	317.5		-	
AdiAbeyto	491612	1698765	1985	Kale Hiwet	110,000	124	5.5	70.7			
MaiAnbesa_old	494068	1698395	1941	Italians	250,000	132	12	150.0			
MaiSirwa	489171	1702196	1963	Italians	2,150,000	174	15	3078.9			
Betmekae	490106	1695039	1989	Kale Hiwet	120,000	70	5	124.8			
Valle-Gnocchi	491253	1702300	Before 1930	Italians	600,000	120	12	1555.0			
Laelay Kelay	493720	1698866	1941	Italians	200,000	100	8	172.4	20		
MaiAnbesa_new	494203	1699060	1988	ECS	350,000	165	8	101.0			
Deki-Zeru	479955	1719039	1987	ECS	50,000	75	8	212.1			500
Adengoda	490641	1711336	1940	Italians	100,000	80	10	492.5			
Afdeyu	484943	1713140	1985	MoA	150,000	120	11	282.3			
Quazien	490809	1708150	1930	Italians		190		109.6			

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR- Currently irrigated area, PIR- Potential irrigable area, HH- Beneficiary households

B. Characteristics of surveyed reservoirs in Zoba Maekel: Subzoba Serejeka

RESERVOIR	Location (Zone P 37) X-UTM	Y_UTM	Year	CONST. BY	DC (M^3)	CL (M)	DH (M)	CA (HA)	CIR (HA)	PIR (HA)	HH
Adikolom	480841	1714035	1989	ERRA	270,000	165	10.5	383.5	5	27	490
Adisheka	488407	1712801	Before 1930	Italians	5,100,000	403	20	3741.7	12	20	213
Beleza	491141	1704784	1958	Italians	1,200,000	120	12	597.4	-		-
Embaderho_D01	488655	1705052	1992	Evangelical	330,000	180	8	239.2	24	33	300
Embaderho_D02	489084	1704885	1965	Private	60,000	73	6	179.8	-	-	100
Guritat_D01	482488	1719380	2006	MoA	300,000	120	11	306.6	6	30	200
Guritat_D02	483941	1718483	1997	MoA	180,000	96	10	223.0	3	18	200
Hayelo	482621	1716791	1995	MoA	1,000,000	80	18	1035.4	40	100	438
Mekerka	483629	1709868	2003	MoA	270,000	100	12	825.9	16	27	350
Mesfinto	486300	1712087	1995	Kale Hiwet	60,000	73	8	97.8	9	6	123
Shmangus laelai	484236	1711011	1985	MoA	400,000	230	9	705.2	15	40	350
Shmangus Tahtai	479493	1713149	1992	Evangelical	230,000	130	8	876.6	15	23	120
Teareshi	481613	1709749	1989	Evangelical	280,000	80	8	1341.1	11	28	198
Zagr	488333	1718554	1984	MoA	150,000	101	7.5	284.4	2	15	814
Adengoda	490641	1711336	1940	Italians	100,000	80	10	492.5			
Afdeyu	484943	1713140	1985	MoA	150,000	120	11	282.3			
Quazien	490809	1708150	1930	Italians		190		109.6			

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR- Currently irrigated area, PIR- Potential irrigable area, HH- Beneficiary households
*Adengoda and Quazien are completely silted and Afdeyu was broken shortly after construction.

C. Characteristics of surveyed reservoirs in Zoba Maekel: Subzoba Berik

	Location (Zone P 37)										
RESERVOIR	X-UTM	Y_UTM	Year	CONST. BY	DC (M³)	CL (M)	DH (M)	CA (HA)	CIR (HA)	PIR (HA)	HH
Adi Merawi	483975	1699660	1992	MoA	110,000	132	8	29.2	3		80
Hazega	482109	1701803	1982	MoA	40,000	45	6	129.4	7		250
Hazega	480910	1703668	1989	MoA	250,000	91	7	123.7	-	25	250
Tseazega	480226	1696267	1988	Evangelical	230,000	230	10.5	3761.7	33.3	23	750
Tseazega	477888	1697066	1983	MoA	150,000	213	8	946.2	-	15	750
TsaedaChristian	483027	1693762	1983	MoA	130,000	200	7.5	184.5	-	13	400
TsaedaChristian	482145	1694886	1944	MoA	80,000	114	6	228.8	4	8	400
Adi Musa	481423	1692616	1992	MoA	250,000	150	8	514.1	2.5	25	150
Adi Ghebru/ Adi Teklay	474129	1694254	1985	MoA	160,000	104	10	324.2	6	16	300
Adi Teklay	472778	1692557	1988	MoA	53,000	105	7	194.0	3	6	150
Adi Ghebru	474135	1696085	2000	Villagers	80,000	90	12	188.2	-	8	655
Tsaeda Emba	484346	1693322	1980	Villagers	55,000	120	5	68.1	2.5	6	250
Wekiduba	488616	1698799	1993	MoA	220,000	226	7	134.5	-	22	350
Shinjibluk	484497	1702572	2007	KR2/MoA	350,000	148	11	232.6	10	35	185
Adi Bidel	478139	1707709	2007	KR2/MoA	90,000	73	9	91.8		9	235
Adi Kontsi-D01	481555	1696180	1970	Villagers	250,000	160	7.5	451.8	2	25	388
Adi Kontsi-D02	481328	1694660	1970	Villagers	70,000	270	4	287.8		7	388

Adi Kontsi-D03	482137	1697270	1970	Villagers	50,000	131	5	85.5			388
Adi Kontsi/ Adi Yacob	480222	1699695	2007	KR2/MoA	200,000	93	10.5	118.6	-	20	250
Ametsi	485355	1706555	1988	ECS	180,000	116	10	166.0	30	12	230
Adi Asfeda	484950	1700905	1988	MoA	200,000	120	11	785.8	32	30	210
Adi Yacob	482128	1700369	1993	MoA	80,000	116	8	133.3	3	8	200
Toker	482403	1706782	2000	Municipality	14,000,000	285	73	14135.8	-		
Daero Paulos	485855	1690172	1987	MoA	60,000	117	7	207.9	2	6	
Adi Habteslus	486247	1700699	1941	Italians	80,000	157	8	489.1	4	8	170
Adisegudo	490128	1697030	1981	MoA	150,000	120	7	521.3			

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR-Currently irrigated area, PIR- Potential irrigable area, HH- Beneficiary households; ECS-Eritrean Catholic Secretariat

Toker is Asmara town water supply reservoir

D. Characteristics of surveyed reservoirs in Zoba Maekel: Subzoba Galanefhi

	Location (Zone P 37)										
RESERVOIR	X-UTM	**Y-UTM**	Year	**CONST. BY**	**DC (M^3)**	**CL (M)**	**DH (M)**	**CA (HA)**	**CIR (HA)**	**PIR (HA)**	**HH**
Tselot_D04	495318	1690282	1984	MoA	50,000	160	8	15.5	-	5	519
Tselot_D03	495718	1687661	1989	ERRA/MoA	250,000	213	8	230.6	2		519
Tselot_D02	496476	1688180	2005	MoA	300,000	92	14	490.7	3	30	519
Tselot_D01	496992	1689892	2007	GMA, MoA	250,000	101	10.5	152.1	-	25	519
Adi Arada	498920	1677829	2007	MoA	200,000	79	12	161.1	3	20	260
Adi-Ahderom	495426	1678399	2007	MoA	250,000	78	12	372.6	12	25	185
Adi Keih	492037	1679069	2007	MoA	40,000	50	7	44.1	-		58
Laguen-AdiHamushte	482664	1683651	1995	MoA	1,300,000	190	22	1093.7	29	130	913
Himbrti Shaka	470634	1687023	1985	ERRA/MoA	400,000	190	10.5	535.5	11	40	1410
Himbrti Gomini	474224	1689001	1989	MoA	450,000	229	11	1128.9	15	45	1410
Himbrti Chea	472628	1685830	1986	ECS	150,000	85	8	721.1	2	15	1410
Embeyto	495617	1682751	1993	MoA	130,000	108	9	167.8	-	13	282
Laguen	483204	1681792	1987	MoA	200,000	137	9	1212.7	15	20	283
Merhano_D01	492468	1687428	1988	Evangelical	250,000	473	8	114.9	-	25	334
Merhano_D02	492125	1690028	1988	MoA	60,000	208	6	753.2	-	-	334
AdiGudad	488495	1687974	1981	MoA	150,000	73	6	272.7	-	15	520
Adi Gombolo	486057	1684220	1982	MoA	150,000	97	7.5	294.7	7	15	316
Kodadu	494668	1681638	1996	MoA	700,000	195	22	457.7	-	70	449
Adi Hawesha	496685	1684824	1988	Evangelical	150,000	105	8	487.6	5	15	406
Selaadaero	487129	1681149	1981	MoA	80,000	113	8	176.2	6	8	245
Adi Keshi	493482	1683585	1988	ERRA	250,000	246	9	165.4	2	25	102
Adi-Tsenaf	491154	1681523	2005	MoA	400,000	170	13	232.6	-	40	1055
Lamza	491234	1683301	1986	MoA	500,000	201	12.5	852.3	18	50	196
Ademzemat	487210	1682548	2006	MoA, RC	50,000	81	4.5	44.0	-	-	200
Mainefhi	476740	1686165	1971	Municipality	26,000,000	200	26	8742.8	-	-	

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR- Currently irrigated area, PIR- Potential irrigable area, HH- Beneficiary households; ECS- Eritrean Catholic Secretariat, RC- Red Cross

E. Characteristics of surveyed reservoirs in Zoba Maekel: Four subzobas of Asmara

	Location (Zone P 37)										
Reservoir	X-UTM	Y-UTM	Year	**CONST. BY**	**DC (M^3)**	**CL (M)**	**DH (M)**	**CA (HA)**	**CIR (HA)**	**PIR (HA)**	**HH**
AdiNfas_D01	493423	1700860	Before 1930	Italians	600,000	190	10	389.2	30		300
AdiNfas_D02	493225	1703000	1941	Italians	200,000	191	9	317.5			
AdiAbeyto	491612	1698765	1985	Kale Hiwet	110,000	124	5.5	70.7			
MaiAnbesa_old	494068	1698395	1941	Italians	250,000	132	12	150.0			
MaiSirwa	489171	1702196	1963	Italians	2,150,000	174	15	3078.9			
Betmekae	490106	1695039	1989	Kale Hiwet	120,000	70	5	124.8			
Valle-Gnocchi	491253	1702300	Before 1930	Italians	600,000	120	12	1555.0			
Laelay Kelay	493720	1698866	1941	Italians	200,000	100	8	172.4	20		
MaiAnbesa_new	494203	1699060	1988	ECS	350,000	165	8	101.0			

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR-
Currently irrigated area, PIR- Potential
irrigable area, HH-Beneficiary households; ECS- Eritrean Catholic Secretariat

Appendix 5: Water Use By-law, Maekel Zone

Work Guidance (By-Law) on Use of Dams and Surroundings
Agricultural Land in Zoba Maekel

Introduction

In Zoba Maekel dams have been under construction since the Italian colonial era for different purposes like irrigation, domestic use, flood control, cooling power for generators and others.

After independence, in 1991about 50 dams have been built in Zoba Maekel for irrigation and domestic use. These dams are designed to hold nearly 13,000,000m^3 of the water, with irrigation potential for 1000ha. Total construction cost of the dams reach about 100,000,000Nacfa with out considering the cost of land leveling and irrigation infrastructure works. But even thought the investment and the irrigation potential of the dams are high, currently irrigated land from the dam is not more than 200ha, which is no more than 20%. This signifies that the dams are under utilized despite the expectation.

The objective of the dams is to promote irrigation to serve for 2-3 times harvesting of vegetables, fruits, flowers spices and animal forage per year. By so doing farmer's income will increase and the dependency of farmers on the unreliable rain fed crops will be reduced. This will contribute to improve the livelihood of the farming society.

In order to correct this problem formulating, binding and motivating work guidance bilow is the result of several workshops and field trips conducted for about three years between the stakeholders. That is benefiting farmers, village elders, women, MOA, administration from Zoba MLW&E at levels agreed and endorsed by high authority.

Definition

Dam: is a structure built on or off stream used to collect water from catchments.
Infrastructure: Hydraulic structure like, dam, outlet spilling, division boxes, gate values, canals, drop structures, drainage canals …etc.
Users (beneficiaries): The villagers who use the dam and the nearby lands.
Ministry of Water Land and Environment: means HWL & E delegates/ offer at different levels.
Administration: Government at different levels/ Zoba, Sub Zoba i.e. Ministry of Local Government offices in Zoba, Sub Zoba.
Ministry of Agriculture: MoA at different levels, in this regard Zoba Maekel and sub zobas in Zoba Maekel.
Work Directive: Means that verify the ownership, management, and utilization of the water, land, infrastructure and the irrigation activity.
Command area: Land to be irrigated by the dam. The land should be suitable for irrigation and is located down or up the stream
Irrigation from the dam: This is production of vegetables, fruits, animal feed, flowers, spices etc by irrigating directly from the dam or from a down stream wells recharged by the dam.

Article One:

1. Heading:

1.1. Work guidance for utilization of dam and nearby agricultural land in Zoba Maekel (Central zone).

Article Two:

2. Regarding ownership of dam

Dams are owned by the government, the farmer's villages around have the right to use as communal or individual or as investor.

The users have to keep, maintain and properly use of the dam. Assistance can be asked from the government for serious structural problems over and above the capability of the users.

Village/Kebabi administration and concerned government body are responsible to control weather the dam is properly utilized.

Village/Kebabi administration if it is over and above, it will be solved by the higher administrative body.

Article Three:

3. Land use of the irrigable area

According to the 2.1 land is owned by government, village/ kebabi administration in collaboration with the government body have the right to distribute and manage the land near the dam or (irrigable area).

3.1.1. Village or kebabi administration in cooperation with the government. Body has the authority or power to distribute the irrigable land to individual farmers, communal irrigators or investors.

3.1.2. If land is distributed for irrigation has not been used within six months after distribution of the land:

Additional three months will be given to him/her to start using the land

If the farmer did not use the land with in the given time frame, the village administration can hand over the land and distribute it to others. In collaboration with the concerned government bodies such as Ministry of Agriculture and Ministry of Land, Water and Environment.

3.1.3. Village/ Kebabi administration will be responsible if the land distribution around the village is not properly developed. Desk Committees have the right to distribute the land to investor or individuals from the village that have the capacity to develop the area properly.

Article Four:

4. Dam management and care

4.1. The village/ kebabi administration and the direct beneficiaries have the responsibility to take care, manage, maintain and properly use the dam in their vicinity or village. The beneficiaries are responsible for problems faced due to negligence.

Article Five:

5. Duty and responsibility of the irrigation development committee (from dam). Committees at zoba, desk and village level will be set to monitor the development process.

5.1. Duty and responsibility of zonal committee

1. Zonal committee will be composed of members from zoba (zonal) administration and branches of ministry of MoA, MWLE and other concerned bodies in the zoba
2. Provide training and due information to beneficiaries or irrigators. Conduct and organize farmer- to-farmer extension and experience sharing from zone to zone
3. Cooperate for technical matters beyond, MoA desk office.
4. Cooperate and help, so that farm inputs, like fertilizer, seeds, hand tools etc will be available to farmers on credit and cash basis.
5. Analyze reports delivered by desk.
6. Monitor if the dam and other hydraulic structures have been abused. If this happened the loss or damage will be made paid.
7. Conduct surveys on market, land fertility, irrigation systems, irrigable land and work for further development.

5.2. Duty and responsibility of desk committee

1. Desk committee will be formulated from desk administration, branch of MoA and Water, Land and Environment and the concerned bodies in the desk (subzoba)
2. Desk committee will report to the zoba committee
3. Desk committee, motivate, give training and due information to farmers.
4. Assist farmers when they face challenging technical problems i.e. over their capacity.
5. Cooperate farmers to get form inputs on credit or cash. The committee will also convey their demands to concerned body.
6. The committees shall advice and control the beneficiaries not to abuse the dam and infrastructure built for them. If any damage occurred due to negligence or mismanagement the beneficiaries will be responsible and the committee will resolve it legally.
7. Desk committee will deliver report every three months to zoba committee

5.3. Duty and responsibility of Village/ Kebabi committee

1. The village committee will be composed of the village/ kebabi administrator, anebaberti (elected village executives work loosely with the administrator) and village executives (work loosely with the administrator) and village development committee.
2. Village/ Kebabi committee will report to desk committees.
3. Distributed land to beneficiaries, investors in collaboration with concerned government body.
4. Control, monitor whether the land distributed to beneficiaries is properly developing.
5. Advice to the lagging farmers or investors to use the land allotted. If not the village committee will take action and inform the desk committee which will take action.

6. Control the dam and irrigation infrastructure from being abused. If damaged the committee will do proper maintenance major in collaboration with the government body.
7. The committee will organize village labor and in collaboration with MoA experts renovate the dam body, the irrigation infrastructure and cut irrelevant trees from the irrigable area.
8. Give advice to farmers to use water efficiently and select crops or vegetables that require minimum water, high yielding in relatively shorter time. Farmers who don't comply will be punished.
9. Inform and warn the villagers not to send their animals to the dam and down stream irrigation area. If this happens, action will be taken to the individual by.village administration.
10. Control whether the outlet of the dam, pump or siphons is operated by the authorized individual.

5.4. Role of beneficiary farmers

1. Beneficiaries are obliged to develop the land on time.
2. Beneficiaries should take care of the dam, irrigation infrastructures like canals, division boxes, drop structures etc and use it wisely.
3. If farmers are not able to develop the land they received, they are obliged to inform the village and desk committee on time.
4. Farmers shall use the technical and professional guidance by the MoA experts in the vicinity.
5. Farmers/ beneficiaries should use the water and land resources they have efficiently.

5.5. Role of communal or community irrigation

In this case a community will be set at village/ kebabi level to assure fair distribution of water, land and control proper utilization of the dam and irrigation infrastructure.

The committee will also be responsible for infrastructure maintenance incase of problem. This committee can be called "water users association" or "committee of water users".

5.5.1. Role and responsibility of "water users association"

1. In collaboration with the village/kebabi administration the committee/ association will make irrigation scheduling so that all the potential command area will be developed. They will also prepare cropping pattern.
2. In collaboration with the village/kebabi administration perform infrastructure maintenance work. If the problem is over their capacity, the committee should report to desk committee via village development committee.
3. Implement the technical and professional advice given by MoA expert regarding irrigation, water management, crops and cropping, plant protection, fertilizer application etc.
4. Organize service operative that can help in marketing. The association can ask credit for service giving institutions.
5. Pushing members who violate the regulation of the association; for serious cases transfer the issue to higher administration body.
6. In collaboration with the village administration distribute water, prepare schedule, employ trained operator. He will be in charge of running motor, open gate and control the system in general paid by the association or growers.

7. The association/ committee shall draft internal bi-law guarding the routine operational aspects like: settling payments of fuel, oil, maintenance, and operator etc. Regarding water payments will be according to the rate set by the Ministry of Land Water and Environment.

Article six:

6. Land management of the area developed by dams

As stated in article three, sub article 1 number 1(3.1.1) all land is owned by government. Village/ kebabi administration in collaboration with concerned government body can allocate the irrigable land around the dam by the following four ways:

1. On village basis under the "water user association".
2. On rental to other farmers
3. Rest of share with external investor
4. If government wants to introduce better system priority will be given.

Article Seven:

7. Land management

7.1. All the rent and sharing agreement should be in line or in accordance with the civil code of Eritrea.

Article Eight:

8. Punishment

8.1. Anyone antagonizing this working guidance will be punished.

Article Nine:

9. Time of implementation

9.1. This working guidance will be active from 16/6/2004.

Appendix 6: Input and output parameters for irrigation scheduling

A. ROOT DEPTHS OF CROPS GROWN IN THE STUDY AREA

CROP	DEPTH(CM)`
BROCCOLI	61
CABBAGE	61
CARROT	60
CAULI FLOWER	61
CUCCUMBER	30-60
GARLIC	30-60
CROPS	150
LETTUCE	30-60
ONION	30-60
PAPERS	30-60
POTATOES	60-90
PUMPKINS	90-120
SPINACHE	30-60
TOMATO	90

B. BASIC INFILTRATION RATES FOR VARIOUS SOIL TYPES

Soil type	Basic infiltration rate (mm/hour)
sand	less than 30
sandy loam	20 - 30
loam	10 - 20
clay loam	5 - 10
clay	1 - 5

Source: FAO, 2005.

C. AVAILABLE WATER CONTENT OF DIFFERENT SOILS

Soil	Available water content in mm water depth per m soil depth (mm/m)
Sand	25 to 100
Loam	100 to 175
Clay	175 to 250

Source: FAO, 2005.

D. SOILS DATA

Depth	Place	PH	Texture class	Texture100%			EC MS/CM	OM (%)	P/ PPM	N(%)	Extructable C mol/kg	CEC meq/100 gm soil
				Sand	Clay	Silt					Ca^{++}, Mg^{++}, K^{+}, Na^{+}	
0-25	H Adesfeda imbirty	7.42	Siltloam	22.8	26.6	50.6	0.07	2.29	13.09	0.09	20 ,7 ,0.23 ,0.87	28.1
0-80	Embaderho	7.96	Loam	45.2	19.4	35.4	0.17	2.25	8.48	0.08	22, 8, 0.15, 1.39	31.54
25-90	Embaderho	7.64	Siltloam	27.5	22.2	50.3	0.11	3.48	7.38	0.13	23, 5, 0.19, 1.18	29.37
0.60	Shimangus Laalay	7.28	Loam	37.7	18.5	43.8	0.09	1.78	13.09	0.07	21, 8, 0.18,0.85	30.03
0.50	Tseazega	7.72	Loam	38.3	23.4	38.3	0.08	2.46	35.42	0.09	21, 5, 0.28, 0.9	27.18
0.60	Adesfeda	6.93	Loam	46.6	18.7	34.7	0.10	2.12	18.23	0.08	19, 6, 0.2, 0.84	26.04
0-10	Adesfeda ADS-SA1	7.55	Sandy loam	71.6	4.2	24.3	0.04	1.14	7.62	0.08	7, 3, 0.16, 0.19	10.4
0-20	Adesfeda ADS-AC1	8.41	Loam	51.2	9.6	39.2	0.2	2.53	72	0.15	18, 5, 0.18, 0.85	24.3
0-20	Ametsi AME-SA1	8.15	Sandyloam	72.6	7.8	19.6	0.09	0.86	30	0.07	15, 4, 0.15, 0.34	19.5
0-20	Ametsi AME-SB1	7.61	Loam	32.7	17.8	49.5	0.13	2.97	37.9	0.14	16, 4, 0.22, 0.42	20.7
0-20	Ametsi AME-SC1	7.93	Loam	44.6	11.1	44.3	0.31	6.19	176	0.36	32, 8, 0.61, 1.05	41.7
0-20	Hayelo/Geshnashm HA-SA1	7.45	Sandyloam	74	10.3	15.7	0.06	1.06	26.6	0.08	15, 4, 0.08, 0.22	19.3
0-20	Hayelo/Geshnashim HA-SB1	8.07	Sandyloam	63.3	11.1	25.6	0.08	1.71	27.7	0.08	10, 3, 0.18, 0.20	13.4
0-20	Laguen-Adihamushte HMT-SA1	8.19	Sandyloam	72.1	11.4	16.4	0.11	1.38	14	0.1	27, 6, 0.63, 0.79	24.5
0-20	Laguen-Adihamushte HMT-SB1	8.24	Sandyloam	57.2	15.9	26.9	0.08	0.96	2.64	0.06	31, 8, 23, 0.74	40.2
0-20	Laguen-Adihamushte HMT-SC1	8.29	Loam	30.5	26.8	42.7	0.15	3.34	29.9	0.18	40, 11, 1.23, 1.18	53.5
0-20	Lamza LMZ-SA1	8.31	Sandyloam	54.4	16.4	29.2	0.17	2.13	29.3	0.15	26, 6, 0.50, 0.67	33.2
0-20	Lamza LMZ-SB1	8.28	Loam	24.9	25.2	49.9	0.21	2.4	54.2	0.15	32, 10, 0.42, 0.69	43.1
0-20	Lamza LMZ-SC1	8.15	Loam	41.3	18.4	40.3	0.27	3.48	60.3	0.19	30, 10, 1.18, 0.77	41.9
0-20	Himbirty-GominiHRT-SA1	7.74	Loam	36.1	23.3	40.6	0.08	3.31	3.65	0.20	24, 6, 0.2, 0.74	31.2
0-20	Tseazega TSZ-SA1	6.87	Clayloam	36.2	28.3	35.5	0.04	1.48	1.73	0.08	12, 3, 0.16, 0.26	15.4
0-20	Tseazega TSZ-SB1	8.15	Loam	41.3	17	41.7	0.11	1.46	4.47	0.07	12, 3, 0.17, 0.78	16.1
0-20	Zagir ZA-SA1	6.7	Loam	48.1	16.4	35.5	0.06	2.3	30.9	0.12	11, 3, 0.16, 0.22	14.4

Comments and recommendations

As per the test result, soil samples 1,3,6,7,8,9,15 and 16 (Adi Asfeda, Ametsi, Hayelo-Geshnashim, Laguen-Adi Hamushte, and Tseazega) have got low N and OM, so have to be supplied with additional corresponding fertilizer either in artificial or natural form. All soil samples except 1, 8, 9, 14, 15, and 16 (Adi Asfeda, Laguen - Adi Hamushte, Himbirty-Gomini,Tseazega) have sufficient P, so the deficient ones have to be enriched with additional P fertilizer. All samples except 5, 8, 10, 11, 12, and 13 (Ametsi, Laguen - Adi Hamushte, Lamza) have low K and so the deficient ones have to be supplied with K fertilizers. All soil samples range between slightly alkaline and moderately alkaline and so are not detrimental to plant growth. The textural classes are mostly sandy loam and loam but only one sample (TSZ-SA1) is clay loam and so all are acceptable for agricultural purposes provided other plant growth conditions such as water-plant-soil management practices are fulfilled. All samples are free from salinity hazards (EC values of all samples are within the norms).Other basic cations and CEC values are within the norms except sample no. 1(of Adiasfeda), which can be improved by adding decomposed OM (humus). Hence, if all the recommended factors for healthy factors for healthy growth of crops such as optimum addition of nutrient elements for the deficient soil samples and proper water-crop-soil management practices are fulfilled, any type of crop which is convenient for the climatic conditions can be grown well. For the low N soil samples, up to 100 kg N/ha in the form of urea can be added in two or three splits if sufficient soil moisture or water input is available. For the low P soils, up to 25 kg P/ha in the form of TSP or DAP can be added during sowing or planting the crop. For the low K soils, up to 100 kg/ha in the form of KCL or NPK fertilizers can be added during sowing or planting the crop. It is worth noting that higher productivity can be found if additional natural fertilizer is added with the mentioned artificial fertilizers for the N, P, K and OM deficient soils. Natural fertilizer (decomposed animal or plant manure) or humus can supply all the necessary plant nutrient elements such as S and micronutrients in addition to the major plant nutrients (NPK). In general, the chemical, physical and biological conditions for the healthy growth of the plant (crop) selected should be fulfilled.

E. Crop Water Requirement Table for some common crop in Zoba Maakel

Crop Tomato   Time step 7   Irrigation efficiency % 50

Date	ETO (mm/Period)	Crop area (%)	Crop KC	CWR (ETM) (mm/ period)	Total rain (mm/ period)	Effect rain (mm/ period)	Irrigation Req. (mm/period)	FWS (L/S/ha)
2\2	31.10	100.00	0.6	18.66	0.00	0.00	18.66	0.62
9\2	32.21	100.00	0.6	19.33	0.00	0.00	19.33	0.64
16\2	33.16	100.00	0.6	19.90	0.00	0.00	19.90	0.66
23\2	33.95	100.00	0.6	20.37	0.00	0.00	2.37	0.67
2\3	34.57	100.00	0.63	21.76	0.00	0.00	21.76	0.72
9\3	35.02	100.00	0.72	25.35	0.00	0.00	25.35	0.84
16\3	35.33	100.00	0.82	28.97	0.00	0.00	28.97	0.96
23\3	35.48	100.00	0.92	32.51	1.19	0.00	32.51	1.08
30\3	35.50	100.00	1.01	35.94	2.37	0.00	35.94	1.19
6/4	35.39	100.00	1.11	39.24	2.93	0.00	39.24	1.30
13/4	35.18	100.00	1.15	40.45	3.63	0.00	40.45	1.34
20/4	34.86	100.00	1.15	40.09	4.36	1.00	39.09	1.29
27/4	34.47	100.00	1.15	39.64	5.00	4.19	35.44	1.17
4/5	34.00	100.00	1.15	39.10	5.38	4.93	34.17	1.13
11/5	33.48	100.00	1.15	38.50	5.33	5.10	33.40	1.10
18/5	32.92	100.00	1.15	37.86	4.65	4.55	33.31	1.10
25/5	32.34	100.00	1.13	36.65	3.11	3.07	33.58	1.11
1/6	31.74	100.00	1.06	33.54	0.66	0.65	32.89	1.09
8/8	31.14	100.00	0.97	30.36	0.00	0.00	30.36	1.00
15/6	30.55	100.00	0.89	27.30	0.00	0.00	27.55	0.90
22/6	21.47	100.00	0.82	17.68	0.13	0.13	17.55	0.81
Total	693.85			643.21	38.74	23.63	619.58	[0.99]

CWR: Crop water requirement for a specific crop calculated as ETo x Kc also called consumptive use (cu).

IR: Irrigation requirement for a given crop in(mm) for a given time set up.

(IR = CWR-Peff) i.e crop water requirement minus effective rain fall.

FWS = Field water supply in l/s/ha assuming continuous supply.

Irrigation efficiency for surface irrigation is taken as 50%.

Crop CABBAGE Time step 7 Irrigation efficiency % 50

Date	ETO (mm/Period)	Crop area (%)	Crop KC	CWR (ETM) (mm/period)	Total rain (mm/ period)	Effect rain (mm/period)	Irrigation Req. (mm/period)	FWS (L/S/ha)
1/9	26.62	100.00	0.70	18.64	37.42	24.40	0.00	0.00
8/9	26.55	100.00	0.70	18.58	24.96	18.89	0.00	0.00
15/9	26.50	100.00	0.70	18.55	12.47	11.95	6.60	0.22
22/9	26.47	100.00	0.71	18.76	2.69	2.69	16.07	0.53
29/9	26.47	100.00	0.77	20.38	0.00	0.00	20.38	0.67
6/10	26.47	100.00	0.84	22.23	0.00	0.00	22.23	0.74
13/10	26.47	100.00	0.91	24.09	0.00	0.00	24.09	0.80
20/10	26.46	100.00	0.98	25.93	0.00	0.00	25.93	0.86
27/10	26.44	100.00	1.04	27.54	0.00	0.00	27.54	0.91
3/11	26.40	100.00	1.05	27.72	0.00	0.00	27.72	0.92
10/11	26.33	100.00	1.05	27.64	0.00	0.00	27.64	0.91
17/11	26.22	100.00	1.05	27.53	0.00	0.00	27.53	0.91
24/11	26.08	100.00	1.03	26.86	0.00	0.00	20.86	0.89
1/12	25.90	100.00	0.98	25.47	0.00	0.00	25.47	0.84
8/12	7.36	100.00	0.95	7.02	0.00	0.00	7.02	0.81
Total	376.73	-	-	336.94	77.54	57.92	285.08	[0.66]

CWR: Crop water requirement for a specific crop calculated as ETo x Kc also called consumptive use (cu).

IR: Irrigation requirement for a given crop in (mm) for a given time set up.

(IR = CWR-Peff) i.e crop water requirement minus effective rain fall.

FWS = Field water supply in l/s/ha assuming continuous supply.

Irrigation efficiency for surface irrigation is taken as 50%.

Crop CARROT Time step 7 Irrigation efficiency % 50

Date	ETO (mm/Period)	Crop area (%)	Crop KC	CWR (ETM) (mm/period)	Total rain (mm/ period)	Effect rain (mm/ period)	Irrigation Req. (mm/period)	FWS (L/S/ha)
1/6	31.74	100.00	0.70	22.22	0.66	0.65	21.56	0.71
8/6	31.14	100.00	0.70	21.80	0.00	0.00	21.80	0.72
15/6	30.55	100.00	0.70	21.44	0.00	0.00	21.44	0.71
22/6	29.98	100.00	0.76	22.73	0.81	0.81	21.93	0.73
29/6	29.44	100.00	0.84	24.73	8.01	8.01	16.72	0.55
6/7	28.94	100.00	0.92	26.67	18.66	17.01	9.67	0.32
13/7	28.48	100.00	1.00	28.58	30.32	23.65	4.92	0.16
20/7	28.07	100.00	1.05	29.47	41.32	28.80	0.67	0.02
27/7	27.71	100.00	1.05	29.09	50.28	32.32	0.00	0.00
3/8	27.39	100.00	1.05	28.76	56.07	34.13	0.00	0.00
10/8	27.13	100.00	1.05	28.49	57.96	34.22	0.00	0.00
17/8	26.92	100.00	1.04	28.08	55.59	32.65	0.00	0.00
24/8	26.76	100.00	1.01	27.03	49.08	29.54	0.00	0.00
31/8	26.46	100.00	0.97	25.97	39.07	25.12	0.85	0.03
7/9	7.59	100.00	0.95	7.23	8.97	6.22	1.02	0.12
Total	408.50	-	-	372.29	416.79	273.13	120.57	[0.28]

CWR: Crop water requirement for a specific crop calculated as ETo x Kc also called consumptive use (cu).

IR: Irrigation requirement for a given crop in(mm) for a given time set up.

(IR = CWR-Peff) i.e crop water requirement minus effective rain fall.

FWS = Field water supply in l/s/ha assuming continuous supply.

Irrigation efficiency for surface irrigation is taken as 50%.

Appendix 7: Participants in the study

A. Extension workers (Enumerators)

S.N	*Name of Participants*	*Organization*	*Job title/post*
1	*Kesete G/giogis*	*MoA*	*Senior soil and water conservation expert*
2	*Musie Welday*	*MoA*	*soil and water conservation expert*
3	*Samul Mosazghi*	*MoA*	*Senior soil and water conservation expert*
4	*Ghebrezgabhier Yemane*	*MoA*	*Agri. Engineer*
5	*Yohanse Tecle*	*MoA*	*Agri. Engineer*
6	*Zeray Gibaat*	*MoA*	*Agri. Engineer*
7	*Ghimay Hintsa*	*MoA*	*Agri. Engineer*
8	*Hrui Amanuel*	*MoA*	*Agri. Engineer*
9	*Amine Teclay*	*MoA*	*Crop production*

B. Workshop Participants (1st workshop held on September 18, 2007)

S.N	Name of Participants	Organization	Job Title/Post
1	AMANUEL NEGASSI	MOA H,Q	DIRECTOR , IRRIGATION
2	BELAY HABTEGABR	MOA H,Q	SINOR IRRIGATION,EXPERT
3	KIFLEMARYAM MHRETEAB	MOA H,Q	SINOR IRRIGATION,EXPERT
4	MHRETEAB BEYENE	MOA BERIK	AMIMAL RESOURSES
5	MEARAF SOLOMON	MOA	FORESTRY
6	MUSSIE HAGOS	REG. ADMINISTRATION	SUB.REGION GOVERNOR BERIK
7	HZKYAS WELDET	ADMINISTRATION	SUB.REGION GOVERNOR
8	ABRAHAM DANIEL	MOA MAAKEL	HEAD IRRATION UNIT
9	BERHANE ANDEMESKEL	M.O.I	JOURNALIST
10	TESFAHIWET MERESEA	ADMINISTRATION	SUB.REGION GOVERNOR,SEREJEKA
11	BIRHANU MAHAMEDNUR	MOA-MAAKEL	HORTICULTURE
12	AYNOM TESFAY	MOA H,Q	IRRIGATION,HYDROLOGIST
13	MUNA ABDELKADR	MOA-MAAKEL	LAND RESOURCE & ENVT
14	HAILE TEKLE	MOA-MAAKEL	HORTICULTURE
15	ASRAT HAILE	MOA-MAAKEL	CROP PRODUCTION
16	RUSSOM ALEM	MOA-MAAKEL	HEAD MOA SEREJEQA
17	TIBERH GAYM	MOA-MAAKEL	HORTICULTURE
18	KESETE GEBREGERGSH	MOA-MAAKEL	SOIL & WATER CONSERVATION
19	ANDETSION ZERAY	MOA-MAAKEL	HEAD MOA BERIK
20	ASMEROM MESFUN	MOA-MAAKEL	CROP PROTECTION
21	TSEGAY YACOB	MOA-MAAKEL	SOIL & WATER CONSERVATION
22	HAILEMICHAEL BERHE	MOA-MAAKEL	HEAD MOA GALANEFHI
23	ZERSENAY KELKEL	MOA-MAAKEL	HORTICULTURE
24	SAMUEL MOSAZGHI	MOA-MAAKEL	SOIL & WATER CONSERVATION
25	YOSIEF TEWELDE	MOA-ASMARA	HORTICULTURE
26	FILMON TESFASLASIE	NWSSA	HYADROGEOLOGIST
27	ZERAY GEBRIHIWET	MOA-GALANEFHI	SOIL & WATER CONSERVATION
28	MUSSIE ISSAC	MOA-ASMARA	SOIL & WATER CONSERVATION
29	MULGETA SIUM	MOA-GALANEFHI	HORTICULTURE
30	TEWELDEBRHAN KIDANE	MOA-ASMARA	ANIMAL SCIENCE
31	TSEGA FESHASION	MOA-SEREJEQA	SOIL & WATER CONSERVATION
32	MUSSIE TEKESTE	MOA-MAAKEL	REGULATORY SERVICES
33	SGALET BAHTA	MOA-MAAKEL	ANIMAL RESOURSES
34	SAMRAWIT TESFAGABR	MOA-BERIK	HORTICULTURE
35	KIBRA ASMELASH	MOA-SEREJEQA	SOIL & WATER CONSERVATION
36	ZAID HAILE	MOA-GALANEFHI	SOIL & WATER CONSERVATION
37	SELAMAWIT TESFAY	-	GIS EXPERT
38	MNEY BERHANE	MOA-BERIK	HORTICULTURE

39	*ROSINA KIFLE*	*MOA-BERIK*	*HORTICULTURE*
40	*MERHAWI OKBAY*	*MOA-BERIK*	*AGRI-ENGINEERING*
41	*G/HER YEMANE*	*MOA-BERIK*	*AGRI-ENGINEERING*
42	*TEKESTE ABRAHAM*	*MOA-MAAKEL*	*ANIMAL SCIENCE*
43	*MUSSIE WELDAI*	*MOA-MAAKEL*	*SOIL & WATER CONSERVATION*
44	*YEMANE ABRHA*	*MOA-MAAKEL*	*DOCUMANTATION*
45	*SEMERE TESFAI*	*MOA-MAAKEL*	*PLANING & STA*
46	*MEBRAT HABTEMICHAEL*	*MOA-MAAKEL*	*FINANCE*
47	*ASMERET ZEKARIAS*	*MOA-MAAKEL*	*AGRONOMIST*
48	*TSEGEWEYNI YEEBYO*	*MOA-MAAKEL*	*HOME ECONOMICS*
49	*ABEBA G/AMLAK*	*MOA-MAAKEL*	*ANIMAL SCIENCE*
50	*MEBRAT TEWELDE*	*MOA-MAAKEL*	*ARD*
51	*ALMAZ SEMERE*	*MOA-MAAKEL*	*ANIMAL FEED*
52	*YOHANNES NEGASH*	*MOA-MAAKEL*	*REGIONAL INSP*
53	*GHENET MELES*	*MOA-MAAKEL*	*MARKETING*
54	*HAILE GHIDE*	*MOA-MAAKEL*	*MOA-MAAKEL ZOBA HEAD*
55	*HAILEAB G/HIER*	*MOA-MAAKEL*	*HEAD OF LAND RESOURCE*
55	*JEMAL SRAJ*	*MOA-MAAKEL*	*PLANNING*
56	*BEREKET ABRHA*	*MAAKEL ADMINISTRATION*	*HEAD, ECONOMIC AFFAIRS*
57	*SOLOMON G/HIER*	*MAAKEL REGION ADMINI-STRATION*	*ECONOMIC AFFAIRS*
58	*HELEN HABTE*	*MOA, HEAD OFFICE*	*SOIL & WATER CONSERVATION*
59	*GHENET G/HIER*	*MOA-MAAKEL*	*AGRONOMIST*

C. Workshop Participants (2nd workshop held on August 22, 2008)

S.N	*NAME OF PARTICIPANT*	*ORGANAZATION*	*JOB TITLE/POST*	*REMARK*
1	*H.E TEWELDE KELATI*	*ADMINISTRATION MAAKEL REGION*	*GOVERNOR*	
2	*BERHANU MEHAMEDNUR*	*MOA*	*HORTICULTURE*	
3	*TECLEAB MENGSTU*	*MOA*	*SUBZOBA HEAD*	
4	*HAILE TECLE*	*MOA*	*HORTICULTURE HEAD*	
5	*ANDEZION ZERAI*	*MOA*	*SUBZOBA HEAD*	
6	*AMAHASION GHRMAI*	*AD.Z.M*	*ADMINSTRATOR*	
7	*KIFLEZGHI KIFLEMARIAM*	*S.Z.BERIK*	*SOCIAL SERVICE*	
8	*GEBREKIDAN GIRMAZION*	*AWSD*	*HEAD OF DEP*	
9	*KIDANE K*	*AWSD*	*DIVISION HEAD*	
10	*KIFLEMARIAM MHRETAB*	*MOA*	*IRRIGATION ENG*	
11	*YOHANNES TECLE*	*MOA-GALANEFHI*	*AGRICULTURAL ENG*	
12	*KIDANE YEMANE*	*MOA-GALANEFHI*	*ANIMAL SCIENCE*	
13	*ZERESENAY KELKEL*	*MOA-SEREJEQA*	*HORTICULTURE*	
14	*MEHRETAB BEYENE*	*MOA-GALANEFHI*	*ANIMAL SCIENCE*	
15	*TESGA TESFASION*	*MOA-SEREJEQA*	*IRRIGATION*	
16	*FILMON TESFASLASIE*	*NWSSA*	*WATER MANAGEMENT*	
17	*TRHAS WELDAI*	*MOA-GALANEFHI*	*SWC*	
18	*ZAID HAILE*	*MOA-GALANEFHI*	*IRRIGATION*	
19	*GEBREZGABHIER YEMANE*	*MOA-BERIK*	*AGRICULTURAL ENG*	
20	*AMANUEL MISGHNA*	*MOA-GALANEFHI*	*AGRICULTURAL ENG*	
21	*TESFAMICAEL YOHANNES*	*MOA-ASMARA*	*AGRONOMY*	
22	*FILMON TESGAI*	*MOA-ASMARA*	*HORTICULTURE*	
23	*MUSSIE HAGOS*	*GALANEFHI-ADMINSTRATION*	*ADMINSTRATOR*	
24	*DAWIT ARAYA*	*MOA-GALANEFHI*	*HORTICULTURE*	
25	*GHEBRAI TECLEAB*	*MOA-GALANEFHI*	*FORESTRY*	
26	*KIFLE GHEBRAI*	*MOA-ZOBA*	*POULTRY*	
27	*ISAIAS ZEWELDI*	*MOA-ASMARA*	*DAIRY*	
28	*ASMEROM TESFALDET*	*MOA-ASMARA*	*LAND RESOURCE*	
29	*MUSSIE WOLDAI*	*MOA-ZOBA*	*SWC*	
30	*MERHAWI OKBAI*	*MOA-BERIK*	*AGRICULTURAL ENG*	
31	*ZERAI GIBAAT*	*MOA-GALANEFHI*	*SWC*	
32	*SEMERE TESFAI*	*MOA-ZOBA*	*PLANNING*	
33	*YEMANE ABRHA*	*MOA-ZOBA*	*DOCUMENTATION*	
34	*SOLOMON GOITOM*	*MOA-SEREJEQA*	*SWC*	
35	*TESFAHIWET MERESEA*	*SUBZOBA SEREJEQA*	*ADMINISTRATION*	
36	*KIBRA ASMELASH*	*MOA-SEREJEQA*	*SWC*	
37	*SOLOMON G/HER*	*ECONOMIC DEVEL-OPMENT*	*HEAD OF ADMINSTRATION*	

38	*EMBAYE BOKRETSION*	*ECONOMIC DEVEL-OPMENT*	*STATISTICS*	
39	*SAMUEL MOSAZGHI*	*MOA-BERIK*	*SWC*	
40	*RIBKA MICHAEL*	*MOA-ZOBA*	*FORESTRY*	
41	*BELAY HABTEGABR*	*MOA*	*IRRIGATION ENG*	
42	*AMANUEL NEGASI*	*MOA*	*DIRECTOR*	
43	*HAILEAB G/HER*	*MOA-ZOBA*	*HEAD OF L.R.C.P*	
44	*KESETE GEBREGERGSH*	*MOA-ZOBA*	*SWC*	
45	*SELAMAWIT TESFAI*	-	*GIS EXPERT*	
46	*EDEN SOLOMON*	*MOA-ZOBA*	*FORESTRY*	
47	*BERHANE KIFLE*	*SUBZOBA- SEREJEQA*	*DEVE-SUBZOBA*	
48	*TESGAI YACOB*	*MOA-ASMARA*	*SWC*	
49	*ZEMEDE TECLE*	*MOA-BERIK*	*FORESTRY*	
50	*MUSSIE HADGU*	*MOA-*	*ANIMAL SCIENCE*	
51	*ASMEROM MESFN*	*MOA-ZOBA*	*REGULATORY*	
52	*EYOB TEKLEMARIAM*	*MOA-BERIK*	*SWC*	
53	*IDRIS ALI MOHAMED*	*MOA-ZOBA*	*VETERNARY*	
54	*HAILEMICHAEL BERHE*	*MOA-BERIK*	*SUBZOBA HEAD*	
55	*MEBRAT TEWELDE*	*SUBZOBA- SEREJEQA*	*ARD*	
56	*JEMAL SERAJ*	*MOA-ZOBA*	*PLANNING*	
57	*HAILE GHIDE*	*MOA-ZOBA*	*HEAD-ZOBA*	
58	*ABRAHAM DANIEL*	*MOA-ZOBA*	*IRRIGATION UNIT HEAD*	
59	*MEBRAT H/MICHAEL*	*MOA-ZOBA*	*FINANCE*	
60	*AKBERET GHEBRAI*	*MOA-ZOBA*	*FINANCE*	

This study deals with the status and the potential of surface water in Upper Anseba Catchment, Eritrea, with a focus on reservoirs and irrigation. Located in the northern part of Zoba Maekel (Central Zone) in the Central Highlands, the Upper Anseba Catchment is one of the most densely populated areas in Eritrea, including small-scale farming areas as well as the urban area of Asmara. Water demand is high and on the increase. The area has no perennial river and depends largely on reservoirs for its water supply.

Summary of key findings:
There are 74 reservoirs in Zoba Maekel, of which 49 are within the Upper Anseba Catchment. Dam construction started during the Italian colonial period; about one third of the reservoirs were constructed after independence.

- Reservoir capacity varies between 40,000 and 26 million m³. Taking into account siltation, which has reduced reservoir capacity by 23% on average, the total current reservoir capacity is 24.5 million m³, which corresponds to 70% of total annual runoff in the Upper Anseba Catchment.

- 29 of the 49 reservoirs in the Upper Anseba Catchment are used for irrigation by local communities. The total irrigated area is 346 ha. This area could be expanded considerably for the benefit of local communities and the country as a whole.

- Recommended steps for upgrading and expanding irrigation include: use of water-saving technology for conveyance and irrigation; irrigation scheduling; establishment of local water user associations; enforcement of existing water by-laws; and preparation of a master plan for water development in the whole area, including all water uses.

ISBN 978-3-905835-14-4

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